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A CRITICAL REVIEW OF THE WORLD LITERATURE IN APPLIED MECHANICS AND THEORETICAL ENGINEERING SCIENCE

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APPLIED MECHANICS REVIEWS

VOL. 4, NO. 7 MARTIN GOLAND *Editor* JULY 1951

THEORIES OF MECHANICAL BEHAVIOR OF MATERIALS

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RESPONSE to load and temperature of solids and pseudo solids is studied in various fields of scientific investigation on different levels and for different types of aggregation of matter (1).[1] Results in one particular field of study are frequently unknown to workers in closely related fields. The wide scope of the study of mechanical properties of materials, its various aspects and their relation to each other are presented in Table I.

TABLE I ASPECTS OF STUDY OF MECHANICAL BEHAVIOR OF MATERIALS

LEVEL OF INVESTIGATION / TYPE OF MATERIAL		ATOMIC AND MOLECULAR	MICROSCOPIC	MACROSCOPIC (PHENOMENOLOGICAL)
CRYSTALLINE	NONMETALLIC	PHYSICAL CHEMISTRY	CRYSTALLOGRAPHY	MATERIALS TESTING; STRENGTH OF MATERIALS
CRYSTALLINE	METALLIC	SOLID STATE PHYSICS	STRUCTURAL THEORIES OF DEFORMATION	ANELASTICITY AND PLASTICITY
CRYSTALLINE	METALLIC	PHYSICAL METALLURGY	MECHANICAL METALLURGY	
"AMORPHOUS"	POLYMER	POLYMER PHYSICS		RHEOLOGY
"AMORPHOUS"	POLYPHASE (HETEROGENEOUS)	COLLOID CHEMISTRY	STRUCTURAL RHEOLOGY	
"AMORPHOUS"	POLYPHASE (HETEROGENEOUS)	SURFACE CHEMISTRY	MICROMERITICS	

One of the difficulties encountered in this study is that most materials are not in thermodynamic equilibrium with their environment; thus, even under perfectly defined conditions of load and temperature, considerable variation in certain properties will occur. These, the so-called "structure-sensitive" properties (deformation properties, cohesive strength, electric resistivity, and magnetic permeability) therefore depend markedly on the history of the material. Whereas theories of "structure-insensitive" properties (density, lattice- and elastic constants, specific heat, and coefficient of thermal expansion) are on a relatively firm basis, theories of "structure-sensitive" properties are in a state of flux. Lack of coordination between different fields of study makes an integrated survey of recent progress in the theories of those properties rather difficult.

1 *Research on Atomic and Molecular Level.* Investigations are concerned mainly with the nature of the cohesive bond and its relation to the atomic structure (2); with the thermodynamics of the processes of nucleation and solidification (3) and of crystal growth (4); with the nature of imperfections in the crystal lattice [dislocations (5), block- and cell-structure (6), grain boundaries (7)] and their effects on deformation, especially creep and work-hardening (8); with the theory of alloys (9); with diffusion- (10) and (reaction-) rate-processes (11) [order-disorder transformations (12), forced phase-transformations (13)] and their effects on large-scale mechanical properties through the creation or removal of textural stresses (14) [recovery and precipitation hardening (15), slip-discontinuities (16) and -delay (17), strain aging and "transition temperatures" (18)]; with the shape of molecules and

[1] Numbers in parentheses refer to the Bibliography at the end of the paper.

EDITOR'S NOTE: The seventh in a series of articles, contributed to APPLIED MECHANICS REVIEWS by international authorities, surveying important topics in applied mechanics.

the configuration of the molecular network in polymers and their effect on polymerization (19) and on mechanical properties (20); with the nature of adhesion and its relation to deformation and strength of heterogeneous materials (21); and, most recently, with mechanisms of disintegration of matter subject to nuclear radiation (22). In most investigations on this level, not more than a qualitative agreement can be expected between a proposed theory and the experiments performed to support it. Although only relatively simple models of real materials have been studied, considerable progress has been made in the formulation of atomic theories of deformation.

2 *Research on Microscopic Level.* More important still, from the point of view of engineering application, is some of the recent progress made in studies of the effects of microscopic structure of materials on their mechanical behavior. A theory of work-hardening of metals has been developed (23) on the basis of the concept of fragmentation of large crystals into a limiting (crystallite) size (24). The essentially viscous response of grain boundaries and slip bands has been demonstrated (25) and its effect on "anelasticity" and relaxation (26), as well as on creep of metals (27) extensively studied. Investigations of the heterogeneity of the deformation of polycrystalline metals (28) and of the resulting microresidual stresses (29) have shown the practical importance of these phenomena. In experimental studies of the mechanisms of deformation of certain polymers, some striking similarities have been found with deformation processes in metals (30). In interpreting the mechanical response of polymers, considerable use is still made of structural or mechanical models (31) into which nonlinear dissipative model elements have recently been introduced (32).

Progress made with respect to structural theories of fracture and fatigue is relatively slow (33). "Statistical" theories of crack initiation and propagation (34) are applicable to brittle materials only. Experimental investigations of crack propagation in metals (35) and nonmetals (36) have shown the basic similarity of the fracture mechanisms in different materials. Increasing emphasis is placed on the deformation process preceding fracture, considering it the most important effect on the fracture phenomenon and assuming that in polycrystalline metals three basic deformation mechanisms exist (37): slip and fragmentation, grain-(cell)-dissociation, and quasiviscous flow. Recent descriptive theories of fatigue (38), as well as proposed procedures of design at elevated temperatures (39) have been based on these assumptions.

3 *Phenomenological Approach.* Investigations are concerned with the existence of an equation of state (40), with conditions of flow of isotropic (41) and anisotropic (42) metals, with dynamic characteristics (43), with the various aspects of deformation and fracture (44), with idealizations of the behavior of real materials (45), and with mathematical solutions of boundary-value problems for idealized materials, such as the linear viscoelastic and the plastic medium. The linear viscoelastic continuum has been effectively dealt with in a small number of fundamental papers (46). Investigations of problems of the plastic ideal medium, however, have been increasing in number so rapidly (47) that recent textbooks (48) present the theory of plasticity as a new discipline of applied mathematics. The engineering significance of these elaborate mathematical studies is severely limited by the fact that their basic assumptions are at variance with the real behavior of metals. It appears that solutions of most of the practically important problems of elastically contained plastic strain on the basis of the well-established isotropic deformation theories (49) provide sufficiently close engineering approximations, unless deformations are large or pronouncedly anisotropic. A theory of plasticity considering this anisotropy has recently been proposed (50).

Future progress will depend strongly on a close coordination of the different fields of study.

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Communications

Concerning AMR 4, Rev. 1650: Antonio Ferri, Supersonic flow around circular cones at angles of attack.

In connection with this review, the following comments are in order:

1 It is stated that "Reviewer notes correct surface pressure is more easily calculated by ignoring effects of vortical layer. First-order Stone-Kopal results are unaffected because pressure is constant through vortical layer." This conclusion is not due to the reviewer, but is stated clearly in the report (see page 16 where it is stated "across this layer the pressure distribution remains constant, but an abrupt equation of entropy occurs," and equation [30]: $p_e = p_c$).

2 It is stated that "Author achieves good agreement between experiment and first-order theory up to $\alpha = 12°$ by retaining certain second-order (α^2) terms in calculating pressure. Reviewer notes this can equally well be done (with identical results) using first-order Stone-Kopal theory." This statement is incorrect. As stated on page 22 of the report, "the theoretical results have been obtained by using the values of reference 4 (Stone-Kopal tables) for the conditions outside the vortical layer." However, the pressure coefficients presented, as stated in the report, are obtained by different expressions. The data of the Stone tables are consistent with the derivation of the equations, where an expression of the form

$$p = p_a + p_b \cos \theta$$

is assumed at first, which does not give satisfactory agreement. The results have been used to $\alpha = 14°$ and not to $\alpha = 12°$, as stated in the review.

3 The statement is made that the reviewer "believes second-order Stone-Kopal theory has been misinterpreted by author. Correct values agree with author's experiments even more closely than do his theoretical data." The theory has been applied exactly by satisfying the boundary conditions in the coordinate system used in the Kopal tables. Probably the reviewer implies that using different coordinate system would give better agreement. The differences, however, are of third-order terms, which are neglected in the analysis.

Antonio Ferri, USA

Concerning AMR 4, Rev. 820: Krzywoblocki, M. Z., On the two-dimensional steady turbulent flow of a compressible fluid far behind a solid symmetrical body.

The statement of the referee that equations (8) and (10) in my paper involve unjustified assumptions is incorrect since equation (8) is copied identically from the cited reference. In both my paper and the reference, that equation refers to "fictitious" fluid. Equation (10) is rigorously derived by applying the rules of the averaging process with the assumption that the equation of state for an ideal gas is valid. This causes $\bar{p}'$ to vanish. In science we always correct all the mistakes regardless of their seriousness. Except some simple cases like ordinary stress tensor in stationary conditions or isotropic turbulence, nobody has shown, up to today, which form an eddy stress tensor possesses: symmetrical or unsymmetrical. There are, rather, indications of an unsymmetrical form and, by means of elementary mixture-length notion, it was shown in my paper that $\tau_{xy} \neq \tau_{yx}$. One cannot forget that we deal with random variables, and complicated mathematical tools must be used to show which form a tensor may possess. The isotropic turbulence with $u' = v'$ [eq. (24) in my paper] was proposed by Prandtl and justified by Schlichting a quarter century ago. That is all explained thoroughly in my paper.

M. Z. Krzywoblocki, USA

Theoretical and Experimental Methods

(See also Revs. 3005, 3024)

2782. **Laitone, E. V., and Ahlin, J. T., A simple graphical solution of the Duhamel integral,** *J. aero. Sci.* **18,** 2, 142–143, Feb. 1951.

A simple but effective graphical method is given for evaluating the Stieltjes integral $q(t) = {}_0\int^t q_1(t)d\delta(t)$, which is important in the study of airplane motion. If the functions $q(t)$ and $q_1(t)$ are given, then $\delta(t)$ may be approximated, by a step function, by a graphical method which is essentially the inverse process of finding the integral. A method for refining the approximation to $\delta(t)$ is indicated. A. Devinatz, USA

2783. **Bukovics, E., Improvement and generalization of the Blaess method for numerical integration of ordinary differential equations** (in German), *Öst. Ing.-Arch.* **4,** 5, 338–349, Nov. 1950.

A method is described for the numerical integration of an ordinary differential equation of the second order which is accurate out to and including the Taylor series term involving the fourth derivative. The new method is similar to those described previously by Blaess [*Z. Ver. dtsch. Ing.* **81,** 587–596, 1937] and Zurmühl [*Z. angew. Math. Mech.* **20,** 104–116, 1940] but is more accurate. It is apparently easier to use than the method of Kutta, which has the same degree of accuracy [cf. Levy and Baggott, "Numerical solutions of differential equations," New York, Dover Publ., 1950, p. 106].

When applied to the differential equation $y'' = f(x,y,y')$ with the initial conditions $y = y_0$, $y' = y_0'$ at $x = 0$, the integration is begun by using Taylor's series out to and including the term in $(\Delta x)^2$ successively over five equal intervals in x. The five trial values of $f(\tilde{f}_0, \ldots, \tilde{f}_5)$ and the initial value of $(\partial f/\partial y')_0$ may now be used to correct the trial values of $\tilde{y}_5$ and $\tilde{y}'_5$ before proceeding with the calculation over the next five increments in x. The correction formulas are

$$y_5 - \tilde{y}_5 = \frac{(\Delta x)^2}{48}(45\tilde{f}_4 + 100\tilde{f}_1 - 145\tilde{f}_0) + \frac{25(\Delta x)^3(\partial f/\partial y')_0}{12}(\tilde{f}_4 + \tilde{f}_1 - 2\tilde{f}_0)$$

$$y_5' - \tilde{y}_5' = \frac{(\Delta x)^2}{24}(11\tilde{f}_5 + 5\tilde{f}_1 - 16\tilde{f}_0) + \frac{25(\Delta x)^3(\partial f/\partial y')_0}{24}(\tilde{f}_5 + \tilde{f}_1 - 2\tilde{f}_0)$$

The method may be generalized for application to an equation of the nth order, in which case it is accurate out to the Taylor series term involving the $(n + 4)$-th derivative of y with respect to x. The necessary correction formulas are given explicitly for the third- and fourth-order equations $y''' = f(x,y,y',y'')$ and $y^{iv} = f(x,y,y',y'',y''')$. R. L. Pigford, USA

2784. **Sobrero, L., On Svoboda's "computing mechanisms"** (in Italian), *Atti Acad. Naz. Lincei Rend. Cl. Sci. Fis. Mat. Nat.* (8), **8,** 5, 480–483, May 1950.

Svoboda's methods of designing linkage computing mechanisms ["Computing mechanisms and linkages," New York-London, McGraw-Hill, 1948] are largely intuitive and empirical. Present paper indicates an analytical approach by showing how a pair of rolling pivoted cams, which impose a given functional relationship between the rotations of two shafts, are replaceable by a connecting rod which joins two conjugate points, one on each cam. Two points are said to be conjugate if each is the center of curvature of the relative path of the other. The points may be taken on the osculating circles of the two cams so that their separation is constant during an infinitesimal rotation except for infinitesimals of the fifth or higher order. M. Goldberg, USA

2785. **Robertson, J. H., A simple machine capable of Fourier synthesis calculation,** *J. sci. Instrum.* **27,** 10, 276–278, Oct. 1950.

A machine for one-dimensional Fourier summation as required in x-ray crystallography is described. Device consists of several sets of wheels, the diameter and speed of which are varied in steps of 1:2:3. . .:15.

It considers sine and cosine terms of wave numbers up to 15 and amplitudes up to 40 units. Small mirrors are operated by means of threads attached to pegs, the distance of which from the center of the wheels of varied speed corresponds to the amplitude of the component. The summation of the mirrors' deflections of a light beam gives the Fourier sum. Machine is inexpensive and simple, its accuracy ±2 units when the average amplitude of the terms is 15–20 units. M. Herbeck, Germany

2786. **Garwin, R. L., A differential analyzer for the Schrödinger equation,** *Rev. sci. Instrum.* **21,** 5, 411–416, May 1950

2787. **Mandel, J., and Mann, C. W., A statistical solution of a problem arising in the sampling of leather,** *J. Res. nat. Bur. Stands.* **46,** 2, 99–105, Feb. 1951.

On evaluating different tanning procedures, one can economize by judicious choice of location for taking test specimens in a hide. Authors conclude from sampling theory that the coefficient of correlation between the test result on a given location and the average of test results on the same property economically determines suitability of the location. The number of hides required to detect a given difference between two tanning procedures is inversely proportional to the square of the coefficient of correlation corresponding to the chosen block and directly proportional to the square of the coefficient of variation of hide averages for the property considered. Albert A. Bennett, USA

2788. **Souriau, J.-M., and Bonnard, R., Error theory in matrix calculus** (in French), *Rech. aéro.* no. 19, 41–48, Jan.-Feb., 1951.

Consider a square non-singular matrix A obtained by observation. Let $A + B$ be true matrix. In first part, author derives a bound for error of A^{-1} in terms of latter and B. Theory is applied to calculate error in eigenvalues of A. Results of this section are either given or implied in a paper by J. von Neumann and H. H. Goldstine [*Bull. Amer. math. Soc.* **53,** 1021–1099, Nov. 1947]. Second part considers problem from viewpoint of probability. Each element of A is given a certain precision. Results are given to evaluate error in elements of A^{-1} and error in eigenvalues. Author does not consider problem of determining error in inverse matrix due to arithmetical operations required to obtain same. For an analysis of this problem, see above reference. Y. Luke, USA

2789. **Neumann, C., A chapter from the lectures by Franz Neumann on mechanical heat theory** (in German), *Abh. Bayer. Akad. Wiss. Math. Nat. Kl.* (*N.F.*), no. 59, 27 pp., 1950.

According to C. Neumann, the unpublished researches of F. Neumann, presented in his Königsberg lectures before 1850 [the year of the first memoir of Clausius on thermodynamics, but after the publications of Mayer (1842) and Joule (1843)], establish his priority as one of the founders of the mechanical theory of heat. F. Neumann's lectures, although worked over and pre-

pared for the press by C. Neumann in 1895, have never been published; the present work, deriving from notes taken in 1854–1855 by H. Wild, is extracted from them, being the third lecture, in which the first law is explained.

Neumann begins by stating that the experiments presented in the preceding lectures show Carnot's view that the change Q in the quantity of heat is a function of caloric u alone is wrong; instead, as D. Bernoulli stated [Hydrodynamica, Deulseckeri, Argentorati, 1738, see chap. X, §§ 1–6], temperature t is a manifestation of molecular motion. In § 1 Neumann considers the state of a substance as defined by a t—u diagram; by first considering paths which are either isotherms or "caloric curves," then regarding a general path as approximated by a zigzag sequence of such paths, he concludes that there is a function $f(t, u)$ such that $Q = {}_A\int^B f(t, u)\,du$, the integral being taken along the particular path connecting state A to state B. This he contrasts with the relation $Q = \Psi(u)$, which he attributes to Carnot. He does not define a caloric curve in this lecture; the quantity u is "the parameter of these curves." To the modern reader it is plain that the caloric curves are adiabates. In this connection it is interesting to notice the observation of LaMer [*Science* **109**, p. 598, 1949], that if Carnot's two terms chaleur and calorique be rendered respectively as heat and entropy, rather than, as is customary, both confounded simply as heat, then the entire work of Carnot ["Refléxions sur la puissance motrice du feu . . .," Bachelier, Paris, 1824] becomes consistent with the mechanical theory; that, contrary to the common statement found in textbooks, there is no error in Carnot's original treatment of the Carnot cycle, was remarked by Callender [see the entry under Heat, Encyclopaedia Brittanica, 11th ed., 1910 to present eds., see §§ 16, 20, 22]. In § 2 Neumann states the First Law in general terms, hence in § 3 concluding the existence of a function $W(p, v)$, where v is the volume and p the pressure acting on a fluid body, such that (*) $dW = \mathfrak{U}f(t, u)du - pdv$, $\mathfrak{U}$ being the mechanical equivalent of heat. The function W, to be identified with the internal energy, Neumann calls Arbeitsvorrat. From (*) he concludes that $\mathfrak{U}(\partial f/\partial t)(\partial(u, t)/\partial(v, p)) = 1$. In § 4 Neumann derives from (*) the fact that it is possible to find a path, connecting two given states p_1, v_1 and p_2, v_2, along which no mechanical work is done, but that in general it is not possible to find a path such that all the energy change arises from mechanical work. Section 5 begins with an indication of how the Carnot cycle can be described in the present terms. By carrying two different substances through Carnot cycles with the same heat reservoirs at the same temperatures, Neumann concludes that it is plausible that if the quantity of heat absorbed by each substance when passing along the first isotherm is the same, then the mechanical work done by each in its full cycle is the same. This statement appears to be equivalent to the Second Law in the form enunciated earlier by Carnot [op. cit.]. Hence Neumann is able to conclude that $f(t, u) = g(t)h(u)$, where the function $g(t)$ is the same in form, up to a constant factor, for all substances. In § 6 he takes account of the kinetic energy of gross motion, stating at the end that when a body is brought to rest in a fluid, the temperature of the fluid must rise.

The reviewer hopes that the remainder of the lectures may be published. According to the introduction to the present one, the first contains an account of an experiment performed by F. Neumann in 1853, in which, by measuring the Joulean heat of a magnetically induced current, he obtained the value 429 kgm/cal for the mechanical equivalent of heat. C. Truesdell, USA

2790. Gordon, C. C., and Richmond, J. C., A thickness gauge for ceramic coatings, *J. Amer. ceram. Soc.* **33,** 10, 295–300, Oct. 1950.

An instrument has been developed to measure the thickness of protective coatings of ceramic materials applied to nonmagnetic metal bases. This instrument provides a nondestructive method of measurement, and can be used for measurements on metallic backings having a wide range of electrical conductivities. Also, the thickness measurement refers to a restricted area and the instrument is, therefore, applicable to curved surfaces. Although developed primarily for measuring the thickness of ceramic coatings on turbine blades and other high-temperature parts of aircraft power plants, instrument should be generally useful in thickness measurements of paint, plastic, and other nonconducting films. The presence of magnetic material in the coating or at the coating-metal interface will vitiate the measurements of coating thickness. From authors' summary

2791. Leidecker, K. F., German-English technical dictionary, New York, S. F. Vanni, 1951, 2 volumes, 968 pp. $35.

A dictionary pertaining to aeronautics, rocketry, space navigation, atomic physics, higher mathematics, jet engines, turbines, hydraulics, petroleum industry, civil and mechanical engineering, ballistics, electronics, radio, radar, meteorology, and other specialized branches. The dictionary has been compiled by the U. S. Air Force and edited by Dr. Leidecker and is of invaluable assistance to readers of German literature in the afore-mentioned branches. Ed.

2792. Nordon, J., Some cases of integrability by quadratures of a differential equation of first order (in French), *C. R. Acad. Sci. Paris* **232,** 2, 140–141, Jan. 1951.

Some forms of $f(x)$, for which the equation $(y')^2 + y^2 = f(x)$ is integrable by quadratures, are investigated by Drach's method [*Ann. Sc. Ec. Nk. Sup.* 37, 1–96, 1920], reducing the equation to a partial differential equation $\partial z/\partial x + r(\partial z/\partial y) = 0$; $r = (f(x) - y^2)^{1/2}$. For a rational solution in the domain $[x, f(x), y, r]$, substitute $Z = P + Qr$, where P and Q are polynomes in y with coefficients that are functions of x. If Q is of degree q, a set of differential relations for the coefficients of P and Q and for $f(x)$ are obtained, which are solved in the cases $q = 2$ and $q = 3$.

In a second case, an integrating factor for the equation $dy - zdx = 0$ is found, which is the n^{th} root of an expression, rational in z and f and, finally, in the cases $f(x) = \exp kx$ and $f(x) = A - \log|\operatorname{tg} x|$, integrating factors are given.

R. Timman, Holland

2793. Topolyanskii, D. B., On the application of variational methods in approximate solutions of boundary problems for differential equations of elliptic type (in Russian), *Prikl. Mat. Mekh.* **13,** 317–320, 1949.

2794. Wasow, W., Random walks and the eigenvalues of elliptic difference equations, *J. Res. nat. Bur. Stands.* **46,** 1, 65–73, Jan. 1951.

Author applies the random walk procedure to obtain solution of the Dirichlet problem for $\Delta u + g(x,y)u = 0$ (*) (Δ is the finite difference Laplace operator) in a finite domain. Brief description of method used is given, along with advantages. Author obtains $E(P,R)$ finite difference analog of normal derivative of Green's function for (*). $E(P,R)$ is shown to be finite if, and only if, the eigenvalues of (*) for the given domain are all positive. A sufficient condition on g for this to be the case is given. $G(P,R)$, Green's function for (*) and $u = 0$ on the boundary is obtained; hence, inhomogeneous problems: (*) $= f(x,y)$, $u = 0$ on boundary are solved. The existence of $E(P,R)$, $G(P,R)$ for unbounded domains is also discussed. Finally, it is shown that the method leads to an approximation of the lowest eigenvalue of (*).

Paper concludes with a comparison of this method with one (awaiting publication) by Donsker and Kac for determining lowest eigenvalue and corresponding eigenfunction for Schrödinger's equation.

Technique involved requires the use of a high-speed computing machine. Author states numerical tests are in progress, but no results of this nature are presented. M. Stippes, USA

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 2848, 3101)

2795. **Hain, K., Periodic angular velocity and torque-changers** (in German), *Z. Ver. disch. Ing.* **93**, 9, 239–244, Mar. 1951.

Examples are given for the graphical construction of four-bar linkages in which the relative oscillating motions of the driving crank and the driven crank have certain desired values. Among the cases considered are: (a) A given velocity ratio for two given positions; (b) three given velocity ratios; and (c) a uniform given ratio over an interval. Similar constructions are given for a crosshead drive. Michael Goldberg, USA

2796. **Wuest, W., High-precision recorder linkages** (in German), *Technik* **5**, 12, 597–600, 586, Dec. 1950.

Paper demonstrates how cardanic pencil carrier linkages for drum recorders may be designed to produce minimum deviation from rectilinear pencil motion and maximum instrument linearity. Several compensating mechanisms are discussed. Analytical expressions for the linkage errors are derived and numerical examples are included. G. A. Nothmann, USA

2797. **Hain, K., Graphical determination of traction curves** (in German), *Ing.-Arch.* **18**, 5, 302–309, 1950.

New graphical method describes constructing space centrode from given path of a point of moving body (A) and body centrode $P_0P_1P_2 \ldots$. Q_0 coincident with P_0 is first point on space centrode. Neighboring point Q_1 is located by trial on arc drawn about Q_0 with radius P_0P_1: it is the center of a circle (radius AP_1) tangential to the given path line. Similarly Q_2, corresponding to P_2, is center of another circle (radius AP_2) tangential to the path line, located by trial on arc drawn about Q_1 with radius P_1P_2.

Method is applied to finding traction curve of simple wheel connected by rigid draw bar to tractor. Wheel axis (usually perpendicular to draw bar) is body centrode; if path of tractor coupling pin is given, space centrode, and hence path of wheel (traction curve), can be constructed.

Wheel attached by multi-link draw bar (steered trailer) also is treated. Solution of inverse problem also is mentioned but not elaborated (construction of draw-bar linkage to steer the trailer on prescribed traction curve for given tractor path).

G. Sved, Australia

2798. **Mikulica, V., Motion of a body under the action of a spring**, *Engng. Rev. Prague* no. 6, 24–27, Dec. 1950.

For use in predicting dynamic behavior of machinery, formulas are derived for linear acceleration, velocity, and displacement of single- and two-degree-of-freedom spring-mass systems. Forces considered are linear spring tension, gravity, and Coulomb friction. Unidirectional motion is analyzed, time integrals of equations of motion being given only for period of decompression or compression of the springs.

While author's formulas are useful in analysis and design of mechanisms, they contain only well-known results.

Holt Ashley, USA

2799. **Taback, I., The NACA oil-damped V-G recorder**, *Nat. adv. Comm. Aero. tech. Note* 2194, 28 pp., Oct. 1950.

An NACA oil-damped V-G recorder has been developed in which viscous damping of the accelerometer results in improved frequency response, reduces susceptibility to vibration, and eliminates necessity for field adjustments of damping. The airspeed element has been temperature-compensated and approximately linearized. The new V-G recorder and its performance characteristics are described and results of tests, which demonstrate the improvements over the older design in which the accelerometer unit was friction-damped, are presented.

From author's summary

2800. **Nordmann, H., Mechanics of train transport** (in German), *Abh. dtsch. Akad. Wiss. Berlin, Math.-naturw. Kl. Jahrg.* 1947, no. 9, 28 pp., 1949.

2801. **Longhini, P., On the formulation and scope of the principle of virtual displacements** (in Spanish), *Cienc. y Tecn.* **115**, 579, 135–151, Sept. 1950.

Author, who believes that the principle of virtual work is "the most general of the laws governing equilibrium of systems," states the principle in its usual algebraic forms, and indicates application to elementary beam problem. By means of principle of virtual work, he obtains a statement of principle of minimum strain energy. James P. Michalos, USA

2802. **Haag, J., Isochronic conical pendulum** (in French), *C. R. Acad. Sci. Paris* **231**, 933–935, 1950.

Author describes a modified and improved form of the Huygens conical pendulum, and shows theoretically that the device can be constructed so as to satisfy modern requirements as to stability and accuracy. A more adequate exposition of the conception will be published later.

Courtesy of Mathematical Reviews L. A. MacColl, USA

2803. **Haacke, W., Investigations on the stabilizing of a double pendulum with periodically vibrating point of suspension** (in German), *Z. angew. Math. Mech.* **30**, 8/9, 233–234, Aug./Sept. 1950.

A plane double pendulum whose point of attachment has a vertical sinusoidal excitation is considered. The equations of motion are found for small oscillation about a nonvertical equilibrium configuration. A perturbation method, using mass ratio between the pendulums as a parameter, leads to Mathieu equations in the perturbation functions. It is found that the angle between the pendulums depends on the ratio of the reduced lengths, and not on the excitation frequency. A transcendental equation previously investigated by Erdélyi relates the angle of the equilibrium position to the excitation frequency.

Robert E. Roberson, USA

2804. **Linderoth, L. S., Jr., Displacement versus time characteristics of hydraulic actuators**, *Trans. Amer. Soc. mech. Engrs.* **73**, 2, 147–154, Feb. 1951.

Displacement versus time characteristic of a hydraulic actuator is determined by applying Newton's second law to the system consisting of hydraulic lines, piston, and load. The pressure drop in the hydraulic lines is taken into account by the Hagen-Poiseuille law in the case of viscous flow, and by the Blasius formula for the case of turbulent flow. The corresponding differential equation is analytically integrable in the first case; for the second case, a semi-graphical integration procedure is given. The theory yields practical results for design purposes. In the discussion, J. D.

Dietiker presents experimental results which are confirmatory in general. J. J. Gilvarry, USA

2805. Miller, H., Analysis of quadric-chain mechanisms, *Prod. Engng.* **22,** 2, 109–113, Feb. 1951.

Proposes use of diagonal of quadric chain as auxiliary parameter for calculation of interrelation of angles between links. Bulk of paper is concerned with calculation of angular velocities and accelerations of quadric-chain links in terms of link lengths and hinge angles; results are given in form of tables of coefficients containing these terms for (a) four-bar linkage, (b) both inversions of the slider crank, and (c) a special mechanism made up of a four-bar linkage combined with an epicyclic gear.

Ewen M'Ewen, England

Gyroscopics, Governors, Servos

2806. Grammel, R., The gyroscope; its theory and applications [Der Kreisel; seine Theorie und Anwendungen] vol. I & II, 2nd. ed., Berlin, Springer-Verlag, 1950, xi + 281 pp., vi + 268 pp.

These two volumes appear to be a revision of a similar work by the same author published before World War II. As a result of author's teaching experience in German colleges and the revision process, these books present a thorough treatment of gyroscopic theory and a great number of good applications. The line-drawing illustrations are numerous and very clear. An appendix to the volume on theory gives a treatment of gyroscopic motion by theta functions.

The shortcomings of the work lie in omissions. If the books are to be used in the classroom or for self-education, there is a lack of illustrative numerical examples and problems. If they are to be used as references for practicing engineers they need more material on gyroscopes as parts of servomechanisms and on modern applications of gyroscopes in controlling and stabilizing vehicles of the aircraft type. For example, only one paragraph is given specifically to the application of gyroscopic theory to helicopters.

W. C. Johnson, Jr., USA

2807. Hochrainer, H., A theory of models for regulator circuits (in German), *Öst. Ing.-Arch.* **4,** 5, 376–387, Nov. 1950.

Author points out the common properties of regulators for different purposes and concludes that a model can be developed by which the regulating process of any regulation circuit may be reproduced and its conditions of stability studied. The model is electrical and consists of a back-coupled valve amplifier.

A graphical method is developed for limiting the area of aperiodic governing in the frequency-response diagram. Such a model has been used in the Polyt. University in Vienna for research on regulation of water turbines. The model controls an electrical motor-generator set, the motor substituting for the water turbine and the corresponding transmission characteristic being imposed on the model electrically. Miroslav Nechleba, Czechoslovakia

2808. Lefèvre, P.-M., Theorem on the so-called essentially unstable linear systems (in French), *C. R. Acad. Sci. Paris* **232,** 6, 475–477, Feb. 1951.

Let the characteristic equation for a linear system be $T(p) - \Lambda = 0$, where T is a rational function with denominator $B_0 + B_1 p + \ldots + B_s p^s$ and numerator $A_0 + \ldots + A_r p^r$. The principal result is that a linear system is essentially unstable if T, written so that $r \geqslant s$ if $\Lambda > 0$, fulfills the conditions: Λ and $B_0 B_s$ are of the same sign; $T(0)$ is zero or of the sign opposite to Λ.

Robert E. Roberson, USA

2809. Pélegrin, M., Contribution to the statistical calculation of servomechanisms (in French), *C. R. Acad. Sci. Paris* **232,** 6, 473–475, Feb. 1951.

Assuming linearity of the servomechanism, a particular form of a message function (with values +1 and −1 taken at random), and a white noise spectrum, author applies the mean square error criterion to the determination of a best transfer function.

Robert E. Roberson, USA

2810. Holoubek, F., Transitional friction effects in powered controls with particular reference to hydraulic jacks, *Aero. Res. Counc. Lond. curr. Pap.* no. 12, 23 pp., 7 figs., 1950.

Operational and graphical approximate solutions of quasi-oscillatory motion induced in a mechanical system by a discontinuous friction function (a sticky piston). Qualitative discussion is presented of design to reduce amplitude and modify frequency of this motion. System is essentially a mechanical analog of a thyratron circuit—the reviewer believes paper suffers from failure to draw this analogy, and that originality of paper lies largely in statement of problem in mechanical terms.

L. B. Hedge, USA

Vibrations, Balancing

(See also Revs. 2822, 2826, 2837)

2811. Baldacci, R. F., On the vibratory motion of a railroad track traversed by a harmonic load (in Italian), *Atti Ist. Sci. Costr. Univ. Pisa Publ.* no. 17, 20 pp., 1950.

Author obtains complete solution for motion of a finite piece of track, elastically supported along the length, rigid simple supports at both ends, under a traveling and harmonically varying load. This reduces correctly to previously known solutions of traveling steady load or harmonically varying load at one point. Then this finite solution is transformed to one for an infinitely long track by a limit process. The critical speeds of the moving vehicle are far above the usual running speeds.

J. P. Den Hartog, USA

2812. Shannon, J. F., and Forshaw, J. R., Propeller blade vibration: nature and severity of vibration at edgewise resonance as influenced by coupling effects due to blade twist, *Aero. Res. Counc. Lond. Rep. Mem.* 2561, 10 pp., May 1941, publ. 1950.

Paper presents stress and amplitude measurements for a non-rotating solid metal blade, excited in a manner to simulate engine torsional oscillations. For the propeller tested, the blade twist caused a strong coupling between the first chordwise mode and the second and third flapping modes; hence there was considerable flapping motion and chordwise stress for all three modes. Author indicates that maximum stress may occur near leading edge of blade, a place which is usually not strain-gaged, but often the place where failure starts. Reviewer wishes to point out that since this paper was written ten years ago, it cannot represent the latest in propeller analysis or testing. Arthur A. Regier, USA

2813. Hagiwara, T., Hasunuma, H., and Inomata, S., A dynamical balancing machine for small size rotors (in Japanese), *J. mech. Lab. Tokyo* **4,** 1, 7–14, Jan. 1950.

Theory and application describe a newly devised dynamical balancing machine that indicates directly the magnitude and location of the unbalance in two planes selected in a rotor. A table, on which the rotor is mounted, is suspended by two flat springs and vibrates in a horizontal plane. The base of the vibrating table

is supported on a soft rubber cushion. The vibration of the table against its base is detected by a milliammeter, and the location of the unbalance is determined by a stroboscopic method.

From authors' summary

2814. **Sahmel, P., Study of vibrations in a floating crane after the load was torn off** (in German), *Glasers Ann.* **73,** 2, 21–27, Feb. 1949.

2815. **Nutt, D. A., Experimental determination of the natural modes of vibration of gas-turbine blades,** *Engineering* **170,** 4423, p. 323, Nov. 1950.

Experimental determination of the principal natural modes of vibration of turbine blades is difficult where bowing, pneumatic or electromagnetic excitation is used. Either the power requirements or excitation of only the simpler modes limits their usefulness. Determination of the various modes is important in turbine-blade design because of the many sources and wide range of vibration excitation inherent in the gas-turbine engine. The method of excitation presented depends upon the electrostatic attraction between two electrodes, of which one is the blade under investigation. An impressed variable-frequency voltage induces vibration excitation of the blade at comparatively low power requirements and practically an unlimited frequency range. Nodal patterns are detected by a piezoelectric pickup. The importance of the excited mode is determined by the damping measurable at resonance by noting the spread of the response curve.

M. P. Hanson, USA

2816. **Weigand, A., Calculation of natural frequencies of spiral springs** (in German), *Z. angew. Math. Mech.* **31,** 1/2, 35–46, Jan.-Feb. 1951.

Springs in the form of Archimedean spirals are considered. The lowest natural frequencies for vibration in the plane and perpendicular to the plane of the spring are found by a Rayleigh approximation. It is shown that for a large number of turns, the frequency of vibrations out of the spring plane can be determined from a transcendental equation involving Bessel functions of order $\pm 2/3$.

Robert E. Roberson, USA

2817. **Villatico, S., Forced vibrations and resonance; application of rotating vectors** (in Spanish), *Tecnica y Economia*, no. 1, 41–46, Sept. 1949.

2818. **Minorsky, N., Parametric excitation,** *J. appl. Phys.* 22, 1, 49–54, Jan. 1951.

Paper outlines a theory of excitation of oscillations under the rather slow variations of a parameter on which a system depends. The basic equation is a Mathieu equation. Basic method consists in reducing the system to polar coordinates and applying perturbations.

From author's summary by Robert P. Felgar, Jr., USA

2819. **Green, P. E., Jr., Magnetic tape recorder for very low frequency phenomena,** *Rev. sci. Instrum.* **21,** 11, 893–895, Nov. 1950.

An apparatus is described for recording electrical signals of frequencies below 100 cps on magnetic tape for subsequent playback. A system of wide deviation frequency modulation of an audiofrequency carrier has been employed to eliminate the difficulties normally encountered in direct recording of low frequency and d-c signals.

From author's summary

2820. **Volterra, E., Vibrations of elastic systems having hereditary characteristics,** *J. appl. Mech.* **17,** 4, 363–371, Dec. 1950.

Paper considers two mathematical forms for stress-strain curves expressing stress as a function of strain and time. Both forms lead to energy dissipation or internal friction within the elastic range. Author mentions briefly the viscous theory wherein the stress-strain relation is given by setting the stress equal to a term proportional to strain plus a second term proportional to the time derivative of strain.

The "hereditary" theory provides a more general stress-strain relation by expressing the stress as the sum of a function of strain, representing the static stress-strain curve, and a term which accounts for the history of the specimen from the initial application of stress to the instant being considered. This term is in the form of an integral over time of the time derivative of strain multiplied by a weighting factor $\phi(t)$ called the "hereditary nucleus" or memory function.

Author considers the problem of determining $\phi(t)$ from dynamic stress-strain tests, and gives experimental results from plastics and rubberlike materials. The memory function is found to be expressible as a sum of terms of the form $\exp(-a_i t)$.

Herbert I. Fusfeld, USA

Wave Motion, Impact

(See also Revs. 3068, 3069, 3096)

2821. **Walters, A. G., On the propagation of disturbances from moving sources,** *Proc. Camb. phil. Soc.* **47,** part 1, 109–126, Jan. 1951.

Author extends previous use of Green's vibrational function (title source, **45,** p. 69, 1949) to obtain disturbance due to point source. Observation was made that the Doppler effect (for sound) due to a supersonic source is different from its classical subsonic counterpart. In the supersonic case, two frequencies are heard simultaneously from the single frequency source.

Application is made of the new type Green's function to the flow around an airfoil in two-dimensional supersonic compressible irrotational flow (including entropy changes in the shock wave).

Keeve M. Siegel, USA

2822. **Hoppmann, W. H., 2nd, Impact on a multispan beam,** *J. appl. Mech.* **17,** 4, 409–414, Dec. 1950.

A capable, analytical treatment of the Bernoulli-Euler equation to find series solutions for deflections and strains in a continuous beam subject to impact by a solid sphere. Effect of damping on the contribution of the higher modes of vibration has not been evaluated and this may well be impractical in a problem of such complexity. Hence, the results are of only qualitative use to the designer of equipment required to withstand mechanical shock. Reader can refer to a paper by Mindlin [*Proc. Soc. exp. Stress Anal.* **V,** no. II] as an illustration of a more exhaustive treatment of a similar shock problem, taking into account the all-important damping and showing to what extent experimental checks can be obtained. It becomes apparent that the designer must fall back on shock testing of actual equipment.

E. G. Fischer, USA

2823. **Lighthill, M. J., The diffraction of blast. II,** *Proc. roy. Soc. Lond. Ser. A,* **200,** 554–565, 1950.

Present paper is a continuation of the work begun in an earlier paper [AMR **3,** Rev. 2716] which concerned diffraction of a blast wave, at nearly glancing incidence on a plane wall, when a corner was encountered. Present paper deals with the reflection and dif-

fraction of blast under nearly head-on incidence with a corner. The corner in each case represents the meet of two planes under an angle close to 180°.

The mathematical methods are very similar to those employed in part I. The results can be summarized as follows: In the case of a corner convex to the shock, the incident shock travels away from the corner in either direction, and in the neighborhood of contact the reflected shock is plane, and is, in fact, that determined by the theory of regular reflection. The flow behind it is, in consequence, uniform. In the vicinity of the corner these properties break down. Within a circle whose center is at the corner, and whose radius grows with the local velocity of sound, shock is curved, flow is nonuniform, and overpressure is relatively weak, owing to the scattering effect of the corner. When the corner is concave to the blast, regular reflection holds until the incident shock has reached the corner itself. Following this, the reflected shock near the corner is curved within a circle, as before; and this circle marks the path of two subsidiary shocks not present in the previous case. Evidence is given to support the contention that much the same state of affairs must exist, even quantitatively, for considerably larger corner angles than those considered here.

Courtesy of Mathematical Reviews D. P. Ling, USA

2824. Sretenskii, L. N., Refraction and reflection of plane waves in a liquid at the passage from one depth into another (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk*, no. 11, 1601–1614, Nov. 1950.

The passage of waves from a basin A with depth h into a basin B with depth ∞ is treated with the velocity potential method. When the angle of incidence is not greater than a value dependent on the frequency and wave length, the waves enter basin B; when the angle of incidence surpasses that value, the refracted waves are extinguished and there is total reflection.

When the waves come from basin B, they always enter basin A. Article gives formulas for the refracted and reflected waves in terms of the incident wave. W. H. Muller, Holland

2825. Pocinki, L. S., The application of conformal transformations to ocean wave refraction problems, *Trans. Amer. geophys. Un.* **31,** 6, 856–866, Dec. 1950.

Paper gives a new method for treating classical refraction problems (i.e., no energy transmission by diffraction is considered). Method may be of value whenever bottom contours are regular enough and a conformal transformation can be found that will map the contours into straight lines or into another simple system.

Principle of the method is: Since Snell's law is valid for any bottom contour configuration, a conformal transformation will map an orthogonal into a new orthogonal.

Treated in detail is the straight beach where the wave length is a linear function of distance from coast (giving circular orthogonals) and, through simple transformations, the solution is applied to special cases of the following problems: Circular island, reef or bay with parabolic contours, and twin islands.

H. Lundgren, Denmark

2826. Mindlin, R. D., Influence of rotatory inertia and shear on flexural motions of isotropic, elastic plates, *J. appl. Mech.* **18,** 1, 31–38, Mar. 1951.

A two-dimensional theory of flexural motions of isotropic, elastic plates is deduced from the three-dimensional equations of elasticity. The theory includes effects of rotatory inertia and shear in the same manner as Timoshenko's one-dimensional theory of bars. Velocities of straight-crested waves are computed and found to agree with those obtained from the three-dimensional theory. A uniqueness theorem reveals that three edge conditions are required.

From author's summary by N. O. Myklestad, USA

2827. Thomson, W. T., The equivalent circuit for the transmission of plane elastic waves through a plate at oblique incidence, *J. appl. Phys.* **21,** 12, 1215–1217, Dec. 1950.

Author studies the transmission of plane elastic waves, incident at any angle, through a stratified medium consisting of a single plate of a solid, with different fluid media on either side. This is a special case of a problem previously treated by author [AMR **4**, Rev. 575] and a generalization of one discussed by Reissner (1938) and by Smyth and Lindsay (1944). Expressions are derived for the ratios of the amplitudes of the various waves, for the transmission and reflexion coefficients of the plate, and for its equivalent electrical circuit. Results are compared with experimentally determined transmission curves for an aluminum plate in water. The agreement is satisfactory as regards the location of the peaks in the (transmission coefficient, angle of incidence) curve; the ordinates of the main peaks do not agree so well and the discrepancy is attributed to dissipation losses.

R. M. Davies, Wales

Elasticity Theory

(See also Revs. 2801, 2826, 2827, 2857, 2858, 2859, 2878)

2828. Belyaev, N. M., Resistance of materials (in Russian), Moscow-Leningrad, Gosud. Izd. Tekhn.-Teoret Liter., 1950. 772 pp. Rubles 22.15.

Fifth edition of this textbook is a revision by colleagues of the late Professor Belyaev. Topics treated are: Concept of stress and strain, riveted and welded connections, combined stresses, torsion, flexure, shearing force and bending moment diagrams; deflections of beams, shafts, and springs; stresses in thin-walled vessels, and statically indeterminate beams. Treated also are curved bars, beams on elastic foundation, thick cylinders, elastic stability of struts and beams, unsymmetrical bending, stresses in rotating disks, dynamic loads, simple vibration problems, and mechanical properties of materials.

Determination is made of strength of statically indeterminate frames and beams in the plastic range, known in the United States as "limit design." Torsional resistance in plastic range is also discussed. The treatment is not extensive but indicative.

Book is well organized, profusely illustrated, and has a pleasing format. Many illustrative examples are solved in detail. Most drawings show ingenuity and care in preparation, and are definite "learning" aids. There are no problems for home assignment.

Rigor and scientific approach prevail throughout the book. References to collateral reading and biblography, however, are absent. S. Sergev, USA

2829. Conway, H. D., Mechanics of materials, New York, Prentice-Hall, Inc., 1951, ix + 352 pp. $6.35.

This new and clearly written textbook is generally suitable for use in the first course on strength of materials as usually taught in American colleges. It covers the topics traditionally included in such courses and, in addition, discusses several important topics which heretofore frequently have been deferred until the second course. Among these are torsion of thin-walled tubes, hyperbolic bending theory for curved beams, stresses in thick-walled circular cylinders and thick spherical shells, Castigliano's theorem, and a rational discussion of theories of failure.

Illustrative examples are presented at the end of each section to demonstrate application of principles which have been dis-

cussed; and, as a further aid to teaching, numerous exercises are included at the end of each chapter. John E. Goldberg, USA

2830. **Polozhii, G. N., Solution of the third fundamental problem of the plane theory of elasticity for an arbitrary finite convex polygon** (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)*, 73, 49–52, 1950.

The third fundamental boundary-value problem of plane elasticity, in author's terminology, is the problem of finding the stresses and displacements in a plane domain G whose boundary is L when the normal displacement and the tangential stress are prescribed on L. An explicit solution of this problem is given in the particular case when L is a bounded convex plane polygon and G is its interior. The solution is based on certain formulas given earlier for the case when the boundary of G is piecewise linear [same *Dokladi (N.S.)*, **66**, 177–180, 1949; *Prikl. Mat. Mekh.* **13**, 297–306, 1949; AMR **3**, Rev. 845]. Using Goursat's formula [*Bull. Soc. math. Fr.* **26**, 236–237, 1898] $\varphi(z) + \bar{z}\psi(z)$, $z = x + iy$, for an arbitrary complex valued solution of the biharmonic equation, where φ and ψ are analytic functions, problem reduces to the determination of the analytic functions φ and ψ. The function φ is obtained at once from the boundary data, and ψ is obtained as the solution of a function theoretic boundary-value problem of the type solved in Muskhelishvili ["Singular integral equations . . .," Moscow-Leningrad, OGIZ, 1946, p. 279]. *Courtesy of Mathematical Reviews* J. B. Diaz, USA

2831. **Birman, S. E., On an effective variant of the solution of the problem of theory of elasticity for an infinite strip** (in Russian), *Prikl. Mat. Mekh.* **14**, 6, 665–669, Nov.-Dec. 1950.

Using contour-conjugate functions, author obtains stress components in infinite strip loaded by two transverse, collinear, oppositely directed, concentrated forces. Formulas for stress components are definite integrals with infinite limits. Numerical calculations present formidable difficulties which author removes and obtains expressions in two parts—one an infinite integral. Discard of integrals introduces, besides concentrated force, a load on contour which author calls "remainder." Influence of remainder in shearing and longitudinal normal stress components being small, author discards integrals and adds negative of remainder to expression for transverse normal stress, thus obtaining approximate solutions in closed form. Comparison of approximate solutions with results of Filon and Melan shows good correspondence.

Uniformly distributed loading applied to finite length of strip is second case discussed. Expressions for stress components again consist of two parts—one an infinite integral. Approximate solutions are in closed form. This case does not have strong discontinuity and is easier to handle mathematically.

Author demonstrates power of complex variable in problems in elasticity. (Application of complex variable to problems in elasticity was first made extensively by Kolosoff and recently by Muskhelishvili.) Reviewer believes author's previous paper [AMR 2, Rev. 165] would help in fully appreciating this one.

S. Sergev, USA

2832. **Weiss, H. J., and Handelman, G. H., A minimum principle for structural stability,** *Quart. appl. Math.* **8**, 4, 395–401, Jan. 1951.

Paper modifies a variational principle of stability formulated by W. Prager [AMR **1**, Rev. 69] and discusses conditions under which eigenvalues are real. Volume integral to be minimized is written $D(u_i) - \lambda H(u_i)$, where u_i are admissible perturbation displacements, $D(u)$ the corresponding strain energy, $\lambda H(u)$ the difference between the work of surface stresses and body stresses on the perturbation strains, λ the eigenvalues sought. By means of standard techniques, paper shows that an equivalent requirement is to minimize $D(u)$ subject to the side condition $H(u) = 1$. This minimum value of $D(u)$ is the corresponding eigenvalue λ. Associated eigenfunctions are shown to be quasi-orthogonal over the volume of the body and, as a result, eigenvalues are real provided $H(u)$ is of one sign for all eigenfunctions. Reviewer notes that in both Prager's paper and in present one there is an error in sign in the coefficients of generalized Hooke's law. Correct expression is $C_{ijkl} = 2G_0[\delta_{ik}\delta_{jl} + (\nu/1 - 2\nu)\delta_{ij}\delta_{kl}]$.

Walter C. Hurthy, USA

2833. **Fridman, M. M., The mathematical theory of elasticity of anisotropic media** (in Russian), *Prikl. Mat. Mekh.* **14**, 321–340, 1950.

Paper is a survey of the development, in Russia, of the theory of an anisotropic elastic body. The first section deals with the formulation of the plane problem, and the existence and uniqueness of solutions. The second section is devoted to effective methods of solution of plane problems. The third section contains a discussion of torsion and bending of anisotropic prismatic beams, and symmetric deformation of anisotropic bodies of revolution. A bibliography of 88 articles concludes the paper.

Courtesy of Mathematical Reviews J. B. Diaz, USA

2834. **Horvay, G., Thermal stresses in perforated plates,** *Gen. Elec. Knolls Atomic Power Lab.*, KAPL-P-456, 83 pp., Jan. 1951.

A method is developed for the analysis of perforated plates of triangular layout, when loading occurs in the plane of the plate. Method is applied to calculation of stresses and distortions that result in a tube sheet when temperature of the sheet is lowered below the temperature of the supporting shell.

From author's summary

2835. **Danilovskaya, V. I., Thermal stresses in an elastic half-space arising after a sudden heating of its boundary** (in Russian), *Prikl. Mat. Mekh.* **14**, 316–318, May-June 1950.

Author considers the effect of inertia force in the thermal stress problem. By imposing a step-function temperature change T_0 at the boundary of a semi-infinite body (initially $T = 0$), author finds a significant effect. At a given section at a distance $x = \text{const}$ from the boundary, the stress X first increases with time from zero to certain negative value less than ST_0, where $S = \alpha(2\mu + 3\lambda)$, α being the coefficient of linear expansion and μ, λ, the Lamé constants. At the instant $t = x/a$, when the elastic wave originated at the boundary reaches that section, X jumps an amount ST_0 to a positive value, and thereafter quickly decreases to zero.

This novel result shows that if really sudden change of temperature at the boundary is possible, then inertia force cannot be neglected, as generally assumed in thermal stress analysis.

Y. C. Fung, USA

2836. **Bogdanoff, J. L., On the theory of dislocations,** *J. appl. Phys.* **21**, 12, 1258–1263, Dec. 1950.

If one or more barriers are introduced in a multiply connected elastic solid and if the strains in the body and their first derivatives are continuous across these barriers, it is proved in the classical theory of dislocations that discontinuities of displacements are possible provided they consist of translation and rotation of one side of a barrier with respect to the other, i.e., displacements which would be possible in a rigid body. Author shows that displacement discontinuities *not* possible in a rigid

body are obtainable if the continuity restrictions on either the strains or their first derivatives or both are removed. The location and shape of the barrier as well as the discontinuity in either the stresses or displacements or a combination of both at each point of the barrier must be specified for these more general dislocations, whereas in the classical theory the shape and location of the barrier are immaterial and only the resultant force and moment acting on the barrier or the rigid body displacements of the sides of the barrier, or a combination of both, are required.

A number of these more general types of dislocations are obtained for states of plane and antiplane strain in a hollow right circular cylinder with a single stationary plane barrier. Reference is made to E. H. Mann [AMR **4**, Rev. 104] for illustrative boundary-value problems, of interest in connection with slip theories of plasticity, which utilize results similar to author's. In reviewer s opinion, inclusion of these or other problems would have aided greatly in gaining an appreciation of the significance and applicability of author's results. Paul Seide, USA

Experimental Stress Analysis

(See also Revs. 2902, 2903)

2837. Kemp, R. H., Morgan, W. C., and Manson, S. S., Advances in high-temperature strain gages and their application to the measurement of vibratory stresses in hollow turbine blades during engine operation, *Proc. Soc. exp. Stress Anal.* **8, 2, 209–228,** 1951.

Authors have developed an improved high-temperature strain gage and techniques of installation enabling the measurement of vibratory strains in a turbine blade up to 1500 F, and measurement of steady-state strains up to 900 F satisfactorily.

The combination of materials used for the measurement of vibratory strains up to temperatures of 1500 F consists of 0.001-in. Karma, or 0.001-in. 80% platinum-20% iridium strain-sensitive wire, 0.010-in. 80% platinum-20% iridium tubular lead wires, L-6AC precoat, and Quigley AAA No. 1925 cover ceramic. Only Karma wire in the unannealed state is suitable as the strain-sensitive element for a strain gage capable of measuring steady-state strains up to 900 F.

A distinct advantage of the strain gage is feasibility of its prefabrication. The strain-sensitive and lead wires are joined together mechanically through the use of a tubular lead, thus avoiding the difficulties of welding.

Results are presented of the measurement of vibratory strains in instrumented blades of a gas-turbine wheel during turbine operation. Maurice A. Walter, USA

2838. Rockey, K. C., Strain gauges in civil engineering, *Civ. Engng. Lond.* **45,** 533, 534; 712–714, 802–804; Nov., Dec. 1950.

This introductory discussion of wire-type electric-resistance strain gages is a brief but complete treatment of gage forms, materials, characteristics, attaching and drying methods, drift, and measurement methods; primarily for readers not acquainted with this type of strain gage. Donald E. Hudson, USA

2839. Todd, J. D., Waterproofing electrical-resistance strain gauges, *Engineering* **171,** 4434, p. 67, Jan. 1951.

A method is described of insulating electric-resistance strain gages so that they can be placed inside concrete. In brief, this consists of completely encasing the gage in brass foil, 0.003-in. thick for the base and 0.001-in. thick for the cover. Details are given for application of the method to the British thermostat type SE/A13 gage, 1000 ohms resistance. The gages give an earth resistance of 8000 to 12,000 megohms when tested in water, and gages cast in concrete beams give the same insulation resistance when tested at the end of 14 days' curing under water. Technique can be used only if the increased force required to strain the brass foil does not affect the required measurements.

E. O. Stitz, USA

2840. Goldschmidt, H. J., A high-temperature X-ray diffraction camera, *J. sci. Instrum.* **27,** 7, 177–182, July 1950.

A versatile 19-cm x-ray diffraction camera, designed to operate up to at least 1400 C, is described. The specimen can be in either a vacuum or a gaseous atmosphere, the attainment of as high a degree of vacuum as possible being a major consideration in design. Camera is suitable for both fiber (powder) or small block specimens. Furnace chamber is heated by platinum-rhodium resistance wire, held by alumina within hemispherical platinum shells, the whole being surrounded by a reflector. Temperature is measured by a movable thermocouple and the pressure by an ionization gage. Two cassettes are located outside the vacuum chamber, which are interchangeable for studies of continuous reactions. They are designed to record Bragg reflections over a wide angular range (up to 86°). Initial performance trials are described. From author's summary

2841. Brookes, P. E., Work-hardening and tempering of steels, *Metal Treatm.* **18,** 65, 75–85, Feb. 1951.

Author has investigated residual stresses in cold-drawn 0.6 and 0.06% carbon-steel wire utilizing x-ray back-reflection techniques. Strains resulting from presence of intergranular and body stresses have been compared with changes in hardness which accompany their formation. The effect of tempering after cold deformation has also been studied.

Results indicate that stresses which exist in pearlitic low-carbon steel are mainly of the long-range body type arising from a non-uniform deformation in different parts of the wire. In the pearlitic high-carbon steels, the stresses are much greater, indicating that the long-range type stress is of secondary magnitude. From observations made by author and other investigators, it is concluded that a system of textural stresses exists between the ferrite and cementite in the latter steel, impeding the full development of the resistance to deformation typical of cold-worked ferrite. Tempering at 150 to 350 C releases these stresses through yielding of the cementite, which in turn is accompanied by an increase in hardness due to the removal of the "Bauschinger effect."

H. R. Neifert, USA

2842. Zangar, C. N., and Phillips, H. B., Photoelastic interferometer determination of stresses around an inspection gallery, *Proc. Soc. exp. Stress Anal.* **8, 2, 187–208,** 1951.

A photoelastic interferometer of the Favre type was used to determine the stresses around a standard 5 × 7-ft inspection gallery of the type used in large concrete dams. Stress coefficients are presented for numerous points on various lines radiating from the galleries; these coefficients relate the normal and shearing stresses on the radiating lines to the unit loads acting on the external boundaries of the model. Boundary stresses determined photoelastically are somewhat higher probably than the stresses existing in a concrete structure because of the relief of stresses by plastic flow in the concrete. Paper makes no attempt to evaluate the effect of plastic flow. Method employed requires point-by-point observation which is somewhat tedious and time-consuming; however, more information is recorded than that obtainable from a simple fringe photograph. Reviewer suggests that slowness of the procedure may lead to inaccuracies since the CR-39 plastic employed for the model exhibits considerable creep and develops undesirable edge stresses with time. However, authors indicate

good checks between observed stresses and equilibrium with imposed loading. T. J. Dolan, USA

Rods, Beams, Shafts, Springs, Cables, etc.

(See also Revs. 2811, 2816, 2822, 2877, 2904, 2912)

2843. **Klitchieff, J. M., Bending of a beam of variable cross section** (in German), *Bull. Acad. Serbe Sci. (N.S.) Cl. Sci. Techn.*, **2**, 77–82, 1951.

The error introduced into the analysis of a tapered beam of unit width and varying thickness is shown to be small when based upon the prismatic beam relation $d^2y/dx^2 = M/EI$. The computation is made by obtaining a corrective term to be applied to M/EI through the analysis of a wedge-shaped member as a two-dimensional stress problem in polar coordinates. The process stems from that of C. E. Inglis and employs a special stress function obtained from J. H. Michell's general solution of the biharmonic equation in polar coordinates.

Joseph S. Newell, USA

2844. **Kindem, S. E., Bending, torsion, and buckling of straight bars with open profile in the elastic domain** (in German), Norway, Tapiers Forlag Trondheim, Diss., 89 pp., 1949.

2845. **Williams, H. A., An investigation of pure bending in the plastic range when loads are not parallel to a principal plane,** *Nat. adv. Comm. Aero. tech. Note* 2287, 61 pp., Feb. 1951.

Reports experimental results on plastic bending tests on 75S-O aluminum beams of rectangular, I, and angle section, with loads in planes 0°, 30°, 60°, 90° to principal planes. A slight modification to Cozzone's method for analysis of symmetric plastic bending is suggested to care for the inclination of the load planes. Report admittedly neglects translation and rotation of the neutral axis, making some use of an "average" of the tension and compression stress-strain curves. Error introduced was small and correlation of test results to results computed by this method were good. Results on the angle section were not too satisfactory.

Duane R. Keller, USA

2846. **Mitsuhashi, T., and Tsuya, K., On the fatigue strength and damping capacity of time-piece springs** (in Japanese), *J. mech. Lab. Tokyo* **4**, 5, 180–185, Sept. 1950.

Authors examined the relation between the damping capacity and fatigue strength of time-piece springs. Results obtained are as follows: (1) Damping capacity of those springs which are oil-quenched and tempered is the lowest at the tempering temperature 300–400 C, when the structure of the spring is most stable and strongest for repeated stress. This low damping capacity and high fatigue strength are due to the fine tempering structure. (2) When spring is tempered at constant temperature, damping capacity decreases rapidly and then increases slowly as the tempering time. This coordinates the relaxation of internal stress and the decomposition of residual austenite. (3) About the austempering, the experimental results are so irregular that no conclusion is drawn. From authors' summary

2847. **Matsumoto, H., and Kamata, K., Form effect of the leaf spring** (in Japanese), *J. mech. Lab. Tokyo* **4**, 5, 186–190, Sept. 1950.

This report studies the effect of lowering the stress concentration of the center bolt hole by changing the hole form. In the bending fatigue limit, $\alpha_k > \beta_k$ and η_k is not constant, where $\eta_k = (\beta_k - 1)/(\alpha_k - 1)$; α_k is stress concentration factor from elasticity theory, and β_k is stress concentration factor from the fatigue test. Next, the effect is studied of lowering the stress concentration of the center bolt hole by changing the section form of the leaf spring. The form employed by the standards increases the fatigue strength. The form of Jeep Type is not good in this test.

Si-Mn steel is used, one rolled (polished), and the other quenched and tempered (sandpaper finishing). Twelve test pieces were investigated. From authors' summary

2848. **Rouverol, W. S., Accurate spring counterbalancing,** *Trans. Amer. Soc. mech. Engrs.* **73**, 2, 141–145, Feb. 1951.

Designers of such equipment as overhead garage doors, automobile trunks, pipe hangers, etc., will find this method valuable for attaining an accurate, full-rotation counterbalance of the weight of hinged bodies by the proper connection of a standard helical spring having a linear load-deflection characteristic.

E. G. Fischer, USA

2849. **Creutz, E., Crushing of aluminum tubes under hydrostatic and localized pressure,** *J. appl. Mech.* **17**, 3, 324–326, Sept. 1950.

All tests were made on tubes of aluminum alloy, 2S, "about $^1/_2$ hard." Under external hydrostatic pressure, results for long thin-walled tubes agree satisfactorily with classic theory. Usefulness of data for thicker walls and shorter lengths is greatly impaired by lack of information on material properties and tube-end conditions. Loading condition referred to as "localized pressure" is not sufficiently defined to permit useful interpretation of corresponding test results. R. E. Newton, USA

2850. **Niemann, G., and Glaubitz, H., Strength of the tooth-root of steel spur gears with straight teeth** (in German), *Z. Ver. dtsch. Ing.* **92**, 33, 923–932, Nov. 1950.

For six statically loaded large tooth models of different forms, the tensions at the tooth root on both sides of the tooth are measured by photoelasticity, and these tensions compared with the endurance limits for a number of steel teeth with pulsating loads, every tooth being conformed with one of the said tooth models, which have modulus 60 mm, while the steel gears have a modulus 6 mm. Some experiments with running gears are also described and compared with the above-mentioned experiments, and authors state that there is a great need for further study in this interesting field. A. R. Holm, Denmark

2851. **Niemann, G., and Glaubitz, H., Strength of tooth flanks of straight steel spur gears** (in German), *Z. Ver. dtsch. Ing.* **93**, 6, 121–126, Feb. 1951.

Destruction of unhardened gears seldom takes the form of tooth breakage, but usually shows up as damage to the rubbing surfaces. As tooth passes through the mesh, the concentrated load on the surface of the tooth may cause minute particles to break away at or slightly below the pitch line (pitting). Paper describes experiments on running gears in order to find the relations between material, load, and mesh number at the beginning of pitting and also to find the influence of the viscosity of the lubricating oil. Finally, the necessity for further experiments is stated. A. R. Holm, Denmark

2852. **Niemann, G., and Glaubitz, H., Small helical spur gears. Influence of the lead upon heating, wear, roll strength, tooth-foot strength and noise** (in German), *Z. Ver. dtsch. Ing.* **93**, 9, 215–222, Mar. 1951.

Comparative tests with spur and helical gears (spiral angle 15° and 45°) showed superiority of the latter as to strength, surface

loading, and less noise. Heating of the gears was nearly the same, only the sliding wear was greater with helical gears. Test results are given in detail and discussed fully. They are a very valuable contribution to gear research. Pavel Kohn, Czechoslovakia

2853. Wittrick, W. H., The properties of crossed flexure pivots, and the influence of the point at which the strips cross, *Aero. Quart.* **2,** part 4, 272–292, Feb. 1951.

Previous work of author [*Austral. J. sci. Res. Ser A*, 1, 2, 121–134, 1948] and J. A. Haringx [AMR, 2, Rev. 954] is extended. Paper shows that rotational stiffness and stability are affected considerably by location of crossover point, and that a particular location, not at center of strips, is best. A side force on the pivot is shown to reduce the rotational stiffness and the linearity of the torque-rotation curve. Formulas for the strain energy in the pivot and for the maximum bending stresses in the strips are derived. G. A. Nothmann, USA

2854. Yu, T. M., Shearing stresses in curved beams, *Sci. Rec. Shanghai*, **2,** 4, 401–408, Nov. 1949.

Author uses the elementary Winkler-Bach theory, which he has found by numerical computation to be in better agreement with available solutions using theory of elasticity than is the Andrews-Pearson theory. Only symmetrical beams curved in plane of symmetry are considered. Results show good agreement with more exact solutions and include straight beam formula as special case. No experimental verification as yet. While flexural stresses govern design of rectangular and circular curved beams, results should be useful for curved beams of I or box section. Applicability to nonuniform sections is suggested but not proved. A. D. Topping, USA

2855. Cowan, H. J., Tests of the torsional strength and deformation of rectangular reinforced concrete beams, *Concr. Const. Engng.* **66,** 2, 51–59, Feb. 1951.

Tests cover five rectangular beams, three having torsion reinforcement consisting of continuous binding (i.e., ties) inclined at 45° on all four beam faces. Author reports that longitudinal corner bars stiffen the beam but torsional reinforcement does so only at larger angles of twist. The secant modulus of rigidity decreases markedly as the angle of twist increases. Strain measurements on the binding agree reasonably well with theory. The factor of safety is more nearly constant if the concrete is assumed to take part of the diagonal tension, as in American practice for stirrup design. Author does not compare Andersen's 1937 tests on spirally reinforced beams. These results seem to agree in the main, but disagree on minor points. Phil M. Ferguson, USA

2856. Ryan, J. J., On the design of rotor-coil support rings, *Trans. Amer. Soc. mech. Engrs.* **73,** 2, 163–166, Feb. 1951.

The design of coils for the rotors of present-day two-pole turbogenerators is such that the centrifugal forces of the coils applied to the rotor-coil support ring are unevenly distributed. Author shows by a two-dimensional analysis of a ring subjected to a uniform loading over only part of its circumference—a condition which approximates the loading over a narrow portion of the rotor-coil support ring—that the deformations and stresses produced are very much more severe than those that would be produced if the loading were uniform over all of the ring circumference. Analysis indicates that an even distribution of the coils is desirable to produce lowest possible stresses in the rotor-coil support ring. Since such a procedure would increase the rotor length by an impractical amount, author suggests the introduction of blocks of material among the coils to aid in providing a uniform distribution of the centrifugal forces transmitted to the support ring.

Author confirms the two-dimensional ring analysis by a photoelastic test, evidently intending that his equations be used for design purposes. Reviewer has some doubt, however, whether these equations would be suitable for other than a qualitative analysis of the nonuniformly loaded three-dimensional structure. Paul Seide, USA

Plates, Disks, Shells, Membranes

(See also Revs. 2831, 2834, 2897, 2898, 2905, 2927, 2940)

2857. Klitchieff, J. M., On the bending of rectangular plates (in German), *Bull. Acad. Serbe Sci.*, **2** (*N.S.*) *Cl. Sci. Techn.*, 69–76, 1951.

Author derives solution to the small deflection problem for a simply supported thin plate with a concentrated load. This solution is a double sine series (Navier solution). He describes how one may obtain by integration of this solution (Green's function) the deflection for a clamped as well as a simply supported plate with arbitrary loading. Paper is mathematical and contains no applications. C. L. Perry, USA

2858. Prokopov, V. K., Flexure of a circular plate under axisymmetrical load (in Russian), *Prikl. Mat. Mekh.* **14,** 5, 527–536, Sept.-Oct. 1950.

"Moderately thick" plate clamped at edge is considered, with deflection of the middle surface vanishing at boundary, and radial displacements vanishing at every point of the cylindrical boundary surface. Load being axisymmetrical, known expressions for components of displacement by one biharmonic function can be used. Author arrives at expression of this function in form of rather complicated series, the general term being function of z multiplied by Bessel's function of r of zero order, with parameter having values of roots of Bessel's function of first order. No conclusions are made, except that in case of "thin" plate, the value of deflection at center coincides with that given by Kirchhoff's approximate theory. J. M. Klitchieff, Yugoslavia

2859. Mushtari, Kh. M., and Surkin, R. G., On nonlinear stability theory of elastic equilibrium of a thin spherical shell under the influence of uniformly distributed normal external pressure (in Russian), *Prikl. Mat. Mekh.* **14,** 6, 573–586, Nov.-Dec. 1950.

Paper concerns problem of buckling of spherical shells and should be considered as a further elaboration of papers by Th. von Kármán-Hsue Shen Tsien, and K. O. Friedrichs. In section 1, essential points of the first paper are outlined. Author's original contribution begins in section 2 in which he uses Ritz's method for minimizing the functional of energy. Calculation of the critical load is carried out in the first and in the second approximations, the difference between the two being about 7.5%. The second approximation gives a 31% greater value for the critical load than the observed one and a nearly three times smaller value than that given by the linearized theory. In section 3 an alternative method is indicated. It is based on the analysis of the condition of equilibrium jointly with the condition of consistency of deformations, and uses the first two terms of Taylor's expansion in the approximation of the trigonometric functions. Results of calculation: 22% above the experimental data for the first, and 8% for the second approximation. The last section, 4, is devoted to criticisms of the two papers mentioned. N. Minorsky, France

2860. **Kilchevsky, N., Approximate methods for the determination of displacements in cylindrical shells** (in Ukrainian), *Zbirnik Prac'Inst. Mat. Akad. Nauk Ukr. RSR.*, no. 8, 97–110, 1947.

Author shows a method of reducing the problem of elastic equilibrium of cylindrical shells to the solution of a system of integral equations, by applying the Betti theorem. In his previous publications on the subject, author used the same method, but in this one he introduces an auxiliary system of displacements in a plate. He uses a special coordinate system through the middle surface of the shell, which allows him to establish a one-to-one correspondence between the points of the plate and the points of the shell. Using the Betti theorem, the solution of the elastic equilibrium of the shell consists of the sum of two quantities: the solution of the elastic equilibrium of the plate, and an expression which depends on the curvature of the shell. The integral equations or, in the case of free boundaries, the integro-differential equations can be solved approximately by iteration, assuming that the curvature of the shell is sufficiently small.

Courtesy of Mathematical Reviews T. Leser, USA

2861. **Haringx, J. A., The rigidity of corrugated diaphragms,** *Appl. sci. Res.* **2A,** 4, 299–325, 1950.

Paper reviews mathematical problem of the circular corrugated diaphragm useful in measuring instruments where deflections proportional to the pressure are required. Essentially, method is to determine approximately, for circular symmetry, two variable (with r) coefficients of rigidity C_1 and C_2, the former being related to the force system and inversely proportional to the angle turned through by the line joining the centers of an unstressed corrugation, and the latter the corresponding moment coefficient. By the device of replacing the corrugated diaphragm by an equivalent flat plate with continuously variable C_1, C_2, a linear second-order equation is constructed. Author assumes that the deformation is such that each half corrugation relates as a whole if the plate is thick, and so C_1r^2 and C_2 are constant and thereby solve the equation. If plate is thin, importance of the corrugation form is obvious and the solutions, with C_1R^2/C_2 large, are obtained for trapezoidal, triangular, and circular (following Stange) forms. Good agreement is shown between this theory and published measurements. Author remarks that "compared on the basis of small deflections, the introduction of corrugations into the sheet leads to a considerable increase of rigidity of the diaphragm. The prevailing assertion that the flat plate is more rigid than the corrugated diaphragm holds only for large deflections, because of the nonlinearity between the load and the deflection of the flat plate." R. C. Knight, England

2862. **Udoguchi, T., Analysis of centrifugal stress in a rotating disc containing an eccentric circular hole,** *Jap. Sci. Rev. Ser. I*, 1, 1, 55–63, 1949.

The problem described in the title is considered as one of plane stress in bipolar coordinates. Author starts with the solution for the concentrically rotating solid disk and then proceeds with the problem of removing the tractions from the boundary of an eccentric circular hole. The tractions are separated into two parts, one of which is self-equilibrating and the other of which has a resultant equal to the centrifugal force of the matter removed from the hole. The former is annulled by employing Jeffery's series solution in bipolar coordinates. The latter is first made self-equilibrating through the use of Mindlin's solution for a disk containing eccentric forces. The remaining tractions are removed only approximately, but it is shown that the residual tractions are small. Author apparently was not aware of a solution by reviewer for an eccentrically rotating disk [*Phil. Mag.* (7) 26, 713–719, 1938]. If this had been used in place of the reviewer's solution for eccentric forces, the author's solution would not have been as lengthy. Paper concludes with results of stress computations and it is observed that the stress in the neighborhood of the hole is similar to that for a semi-infinite plate, containing a circular hole, under a uniform tension parallel to the straight edge. The latter problem was considered by Jeffery and an error in it was noted and corrected by the author [*Trans. Jap. Soc. mech. Engrs.* **13**, 17–40, 1947] and the reviewer [*Proc. Amer. Soc. civ. Engrs.* **65**, 619–642, 1939; *Proc. Soc. exp. Stress Anal.* **5**, no. 2, 56–68, 1948]. R. D. Mindlin, USA

2863. **Clark, R. A., and Reissner, E., Deformations and stresses in Bourdon tubes,** *J. appl. Phys.* **21,** 12, 1340–1341, Dec. 1950.

The stresses and deformations of Bourdon tubes with elliptical cross section are studied from the point of view of thin shell theory. It is found that solutions depend primarily on two dimensionless parameters which involve the dimensions of the tube. These parameters are of the form b/c and bc/ah, where a is radius of center line, h wall thickness, c major semi-axis of the elliptical cross section, and b minor semi-axis. There exist two limiting solutions, the elementary beam theory solution for "thick-walled" Bourdon tubes ($bc/ah < 0.5$) and the membrane solution for "thin-walled" Bourdon tubes ($bc/ah > 10$). Two different methods of solution with consequent overlapping of the range of validity were employed. Unfortunately, the asymptotic results for the sensitivity of thin-walled tubes, although of qualitative interest, are not at all in quantitative accordance with (unpublished) measurements made by the reviewer on Bourdon tubes with elliptical cross section. Walter Wuest, Germany

2864. **Höhn, E., Calculation of flat flanged boiler bottoms** (in German), *Schweiz. Bauztg.* **69,** 3, 25–29, Jan. 1951.

Calculation of flat-flanged boiler bottoms, stayed in the center, has till now been performed by empirical formulas. Measurements on such bottoms showed that the distribution of stresses in the flat region is similar to that in a circular plate with circular hole at center, both edges clamped and supported. Influence of the knuckles, which the theory of the circular plate does not respect, is brought into agreement with the results of the measurements, and a simple formula for calculating such boiler bottoms is given. Pavel Kohn, Czechoslovakia

2865. **Malkin, I., Stress analysis of a hemispherical pressure vessel head under concentric line loads,** *J. Franklin Inst.* **251,** 2, 247–261, Feb. 1951.

Author works out a complete numerical procedure for the stress analysis of the hemispherical head of a cylindrical pressure vessel. Vessel is under an internal pressure, and, in addition, is acted upon by line loads uniformly distributed along several concentric circles drawn on the sphere symmetrically with respect to the axis of the vessel.

Author follows Timoshenko's "Theory of plates and shells" in the formulation of the problems of spherical and cylindrical shells of constant thickness. In the spherical shell case, Geckeler's approximate solution (i.e., the neglect of the terms containing the functions $Q\varphi$ and V and their first derivatives in the differential equations) is used. The problem is set up by taking all loads simultaneously into consideration, and is reduced to the determination of $4m + 7$ unknown constants (where m is the number of loading circles). These are determined by the boundary conditions and conditions of continuity at each of the loading circles and at the connection of sphere and cylinder.

It occurs to reviewer that author's solution can actually be ob-

tained by the superposition of several simple solutions, each involving only one load at a time. T. H. H. Pian, USA

2866. Stoker, J. J., Prestressing a plane circular plate to stiffen it against buckling, *Proc. Symp. appl. Math.* **3,** p. 129, 1950.

2867. Eisenhardt, G. H., and Rohsenow, W. M., Calculation of thermal stresses in a wedge-shaped wing, *J. aero. Sci.* **18,** 2, 115–123, Feb. 1951.

At extremely high flight speeds, frictional effects in the boundary layer produce extremely high temperatures and temperature gradients within aircraft structures. Time-space temperature distribution for a diamond airfoil had previously been calculated by another author [see Kaye, J., AMR **4**, Rev. 2137]. Present paper gives method for calculating thermal stresses in this airfoil. A solid, semi-infinite double-wedge steel wing is assumed flying at 50,000 ft and accelerated uniformly from Mach 1.4 to Mach 6.0. Thermal stresses at instant wing reaches Mach 6.0 are calculated, assuming elastic properties of steel at room temperature. Interpolation method is presented for estimating thermal stresses during acceleration. Stress values obtained are incredibly high due to assumption of elastic behavior. Actually, plastic flow and buckling would reduce these values. Purpose of paper is to demonstrate method, which is applicable to other shapes and materials, rather than to present numerical results.

B. F. Langer, USA

2868. Agnelluzzi, L., Modification of the Marcus method (in Italian), *G. Gen. civ.* **89,** 1, 37–44, Jan. 1951.

The simplified method of Marcus for determination of stresses in isotropic plates ["Die Vereinfachte Berechnung biegsamer Platten," Berlin, 1925] is modified according to Nicolsky [*C. R. Acad. Sci. Paris*, 1938] in order to determine the steel reinforcements in orthotropic reinforced concrete plates. The reduction in steel reinforcement is given in two series of graphs for simply supported and for built-in plates. Mario G. Salvadori, USA

2869. Leggett, D. M. A., and Hopkins, H. G., The effect of flange stiffness on the stresses in a plate web spar under shear, *Aero. Res. Counc. Lond. Rep. Mem.* 2434, 12 pp., Nov. 1941, publ. 1950.

Paper deals with beams having two flanges joined by a thin web reinforced by stiffeners perpendicular to flanges. A uniform load acts tangentially on upper flange, and an equal and opposite load acts on lower flange, producing shear in beam. It is assumed that stiffeners remain straight, and web buckles into a series of parallel diagonal waves. By consideration of web as made up of a series of filaments parallel to wave crests, the elastic energy of one panel of beam is computed as function of infinite set of parameters specifying deformation of beam. These parameters are chosen to minimize strain energy. This entails approximate solution of infinite set of equations. Results indicate that, in the practical range, the variation with flange stiffness of both shear stiffness of web and maximum flange bending moment is small.

G. E. Hay, USA

2870. Gittleman, W., Circular plates of nonuniform thickness, *Aircr. Engng.* **22,** 258, 224–227, 237, Aug. 1950.

An approximate method is presented for calculating stress distribution in circular plates of variable thickness, supporting a uniform load. Plate is divided into concentric rings of uniform thickness (steps). Equations are derived for the sum and difference of the radial and tangential stresses needed in proceeding across the ring element and across the interface of two rings. Equations are applied twice and the correct solution obtained by use of the sum and difference of stresses at the boundaries (or center, if plate has no annular, central hole).

Paper is illustrated by an example in which the method is applied to a problem whose theoretical solution is known. Good agreement is obtained. Reviewer believes this method is of great practical value. Vito L. Salerno, USA

2871. Swida, W., The plate equations for the elasto-plastic state (in German), *Z. angew. Math. Mech.* **30,** 11/12, 375–381, Nov.-Dec. 1950.

Following assumptions are made: Small deflections compared with the plate thickness; points on a normal of the middle surface remain on a normal; Mises-Hencky yield criterion is valid; after yielding, the stresses remain constant in the plastic zone. A complicated set of equations is given for the deflection of the middle surface, the boundary of the plastic zone, and for the stresses. The equations are simplified in the case of pure bending and in the case where the problem is independent of one of the coordinates. A numerical example is given.

W. L. Esmeijer, Holland

Buckling Problems

(See also Revs. 2832, 2844, 2849, 2859, 2866, 2890)

2872. Hoblit, F. M., Buckling load of a stepped column, *J. aero. Sci.* **18,** 2, 124–126, 138, Feb. 1951.

Paper presents procedure for calculating buckling load of a column, under any end conditions, having n segments of constant stiffness. Procedure generally requires (a) assumption of value of buckling load; (b) starting at the near end of the column, step-by-step calculation, by means of equations developed in paper, of deflections, slopes, and moments at the ends of the segments; (c) adjustment of assumption for buckling load until boundary conditions at far end of column are satisfied. Procedure is similar in spirit to Holzer-Myklestad method in vibrations. Application to several specific cases is described briefly, without numerical illustrations. Bernard Budiansky, USA

2873. Belluzzi, O., Simplified calculation of buckling loads for columns partially embedded in an elastic ground (in Italian), *G. Gen. civ.* **88,** 11, 631–638, Nov. 1950.

Buckling loads are computed by integration of Euler's differential equation or by energy under the simplifying assumption that the underground portion of the column is not under compression and is long in comparison with the free portion. The error due to these assumptions is proved to be negligible in most practical cases. Columns are assumed free or pinned at the top, and free to move laterally or restrained against lateral displacement at the bottom. Mario G. Salvadori, USA

2874. Nowacki, W., On stability problems of an orthotropic plate (in French), *Arch. Mech. stos.* **2, 3,** 169–182, 1950.

Mathematical solutions are obtained for the buckling of a flat plate loaded by a concentrated load or loads applied normal to the edges, in the plane of the plate. The results are given as curves showing how the buckling coefficient varies with the proportions of the plate. F. R. Shanley, USA

2875. Goodman, S., Lateral elastic instability of hat-section stringers under compressive load, *Nat. adv. Comm. Aero. tech. Note* 2272, 35 pp., Jan. 1951.

Analysis is for symmetrical hat sections having flat tops and straight or angular sides. It is assumed that sides are fixed at

bottom, lateral displacement of top is a sine curve, and axial displacements of sides at top are cosine curves. Minimum critical stress is found by equating strain energy stored in stringer due to buckling to that put in by load and eliminating the two parameters involved in the assumed displacements. Calculations are made for five stringer sections having height-width ratios of 2.5 to 5 and width-thickness ratios of about 7. Calculated critical strains are well into the plastic range, so another method is developed involving five parameters and sides hinged at bottom. Calculations are made for one stringer with results 34% lower than by first method.

Reviewer wonders whether the difference in numerical results is due to use of more refined deflection expressions or to hinged instead of fixed sides; also, if high numerical values are perhaps typical only for the relatively thick stringers calculated. T. J. Walker of Carnegie Institute of Technology has adapted author's two-parameter method to hinged sides and has found that this checks the author's five-parameter calculations very closely. It can thus be concluded that the simpler method is as satisfactory numerically as the more complicated one. Lower bounds for critical stress can also be calculated using the two-parameter method and hinged sides. Taking $E = 10^7$, lower bound varies from 688,000 psi for height-width ratio of 1 to 61,000 psi for 5 and 17,000 psi for 10. Apparently, elastic instability, for present alloys, is only likely to occur for height-width ratios above 5. C. M. Tyler, Jr., USA

2876. **Levi, F., and Capra, V., Influence of viscous deformations upon the conditions of equilibrium stability** (in Italian), *Ric. sci. Rome*, **20**, 11, 1662–1666, Nov. 1950.

Authors claim to indicate by two examples that the Euler crippling load of a column is not altered by the presence of viscous stresses. They suppose the viscosity to be linear, but they do not state precisely what law it follows, nor can the reviewer understand their analysis or results, which are presented in terms of an unexplained and undefined symbol. C. A. Truesdell, USA

2877. **Flint, A. R., The stability and strength of slender beams,** *Engineering* **170,** 4430, 545–549, Dec. 1950.

Paper aims at establishing design criteria against lateral buckling for transversely loaded, slender beams without lateral support. Method parallels reviewer's earlier treatment [*Trans. Amer. Soc. civ. Engrs.* **112**, p. 527, 1947] in applying yield criterion to initially imperfect beams, except that inherent imperfections are represented by initial, horizontal curvature of beam in sine half wave, instead of reviewer's initial inclination of loading plane. Results are similar, and final formulas are of about equal complexity. In the mathematical treatment the effect of the warping rigidity is neglected in determining displacements, although warping stresses are implicitly recognized when computing stresses from these displacements. Subsequent correction of displacements for warping rigidity is carried out in an approximate manner. Conclusion that such correction need not be considered in design is misleading, since (a) author's claim that correction is negligible for $L/b \geq 40$ is contradicted by his own numerical results, and (b) for most practical beams $L/b \leq 40$ so that the warping effect is substantial. Initially straight beams loaded off shear center are treated briefly by similar methods.

Interesting testing arrangement is described briefly, which realizes end conditions very accurately and provides loading by suspended water tanks rigged so as not to restrain rotation. This is the best loading arrangement reviewer has seen for tests of this kind. Test results on three I-beams agree well with theory. However, slenderness of these test beams were extremely high (L/b = 96 to 116), at which values the effect of warping rigidity is indeed negligible. Less satisfactory agreement would have been obtained with shorter beams of more practical dimensions. Statement that "only a small increase in load-carrying capacity is obtained by continuing loading into the plastic range," likewise, is valid only for these extremely slender beams.

George Winter, USA

2878. **Sesini, O., On the approximation of energy methods for the calculation of eigenvalues** (in Italian), *Termotecnica* 5, 2, 94–99, Feb. 1951.

The critical load for a hinged column can be found approximately from $P = \int EIy''^2\,dx / \int y'^2 dx$, or $y'^2\,dx / \int y^2/EI\,dx$. At the expense of more calculational work the second formula yields—with the same $y(x)$—the better value for P. Rearranging both expressions by means of a development of y in a series of eigenfunctions and by connecting the formulas with the method of successive approximations, author shows *why* the second formula must be better. Numerical examples: Euler column and critical angular speed of shaft clamped on both sides. K. Marguerre, Germany

Joints and Joining Methods

(See also Revs. 2899, 2955, 2956)

2879. **Hartmann, E. C., Holt, M., and Eaton, I. D., Static and fatigue strengths of high-strength aluminum-alloy bolted joints,** *Nat. adv. Comm. Aero. tech. Note* 2276, 61 pp., Feb. 1951.

Results of static and fatigue tests on joints in 75S-T6, 24S-T6, and 14S-T6 high-strength aluminum-alloy extruded bar are given. In addition, a monobloc specimen was tested to evaluate the sensitivity of the materials to the effects of a notch. Comparisons are made of the following types of joint designs: Nonuniform-step, plain-scarf, bolted-keyed, serrated, single-shear, double-shear, uniform-step, clamped-keyed, and double-scarf.

From authors' summary by F. L. Singer, USA

2880. **Fountain, R. W., and Stout, R. D., Relative strain-aging tendency of weld and base metal,** *Weld. Res. Suppl.* **16,** 1, 43s-46s, Jan. 1951.

Carefully planned tests indicate that the heated zone of welded joints is primarily responsible for strain aging or the loss of ductility and notched toughness in welded plates after being heavily stressed. Unwelded plates, plates with deep welds and shallow notches, and plates with shallow welds and deep notches extending through material heated to critical temperatures showed no strain aging. Plates with shallow welds notched through most of the weld or notched just below the fusion line exhibited clearly the effect of strain aging. C. H. Clarahan, USA

2881. **Welter, G., Stresses around a spot weld under static and cyclic loads,** *Weld. Res. Suppl.* **15,** 11, 565s–576s, Nov. 1950.

Spot-welded mild steel sheets of 0.03-in. thickness put under tension loads up to 600 lb indicate usual compression stresses at the outside surface around the spot; slight tension stresses were measured only at a small distance above the spot in the axis of the joint. Measurements made at interface of the joint, instead of its outside surface, show that, due to bending of the sheet, tension stresses exist exclusively above the spot, having fairly pronounced values.

Under cyclic tension load, fatigue cracks start at interface of the weld, due to repeated bending of the sheet in a zone close to the spot. These cracks develop a long time before they become visible at outside surface of the sheet. Fatigue results obtained

with mild steel specimens of 0.04-in. thickness, obtained on three different pulsators, show that hydrostatically treated spots have a 25 to 50% higher fatigue limit than untreated joints. Similar results have been obtained with spot-welded 0.03-in. thick stainless-steel sheets. Hydrostatic compression of the spot is even more effective on 24S-T Alclad aluminum-alloy sheets; an improvement of 80 to 100% of their endurance limit is possible.

E. Siebel, Germany

Structures

(See also Revs. 2838, 2842, 2855, 2872, 2875, 2934, 2965)

2882. Wierzbicki, W., Structural mechanics, 4th ed. (in Polish), Warsaw, Students' Publ. Co-operative, 1949, xv + 660 pp.

This very good handbook is written chiefly for students of polytechnical schools. Conforming to the curricula of these schools, it is limited to the theoretical problems and calculations of structures and does not include descriptions of the structures themselves, as is often done in English handbooks. The main object of the book is to teach, but it also contains a more comprehensive discussion of those scientific problems which were the object of the author's studies; e.g., calculation of elastic arches, based on the development of the theory of the least squares; relation between the geostatic pressure and geodynamic pressure; a comprehensive discussion of buckling; the theory of polygonal bars, etc. Latest literature on the subject is given in footnotes. The plan of the work is as follows: *A.* Plane systems and torsion of straight bars: (a) Full systems, (b) framework systems, (c) suspension chains and carrying lines, (d) retaining walls and gravity dams. *B.* Space systems: (a) Full systems, (b) framework systems. There are also chapters on safe stress, strain energy, and dynamic strength. An index of structural mechanics terms in Polish, French, English, German, and Russian is appended.

K. Zarankiewicz, Poland

2883. Le Nobel, J. C., The exact Cross method compared with the usual theoretical calculations (in Dutch), *Ingenieur* **63**, 4, B1–B5, Jan. 1951.

In a previous paper [AMR **4**, Rev. 2445] author proposed a procedure taking advantage of the geometrical series of moments arising in the usual Cross method to transform it in an exact calculation. In present paper, this modified Cross method is compared to the usual theoretical procedures in order to show that (a) results of both are in accordance, and (b) exact Cross method has special work-saving qualities.

Reviewer must observe that point (a) was superfluous because of Kirchhoff's theorem on the unicity of solution. Comparison of the new calculation with Gehler's method in the case of a two-story frame without side sway is somewhat misleading, as the author's solution by Gehler's method is unnecessarily complicated.

Ch. Massonnet, Belgium

2884. Rathgeb, E., Considerations on adequate selection of the fundamental system for the solution of hyperstatic structures (in Spanish), *Cienc. y Tecn.* **116**, 584, 53–62, Feb. 1951.

The problem of the resolution of statically indeterminate structures has two different aspects. The first is a conceptual one and the second is related to the practical application of those concepts. Generally, in technical papers, only first aspect is studied, which offers no real difficulties; the second appears in practical cases, such as problems of transmission of errors to the results that may invalidate them, or as a large amount of material work of calculus for the solution of the problem. In the present article, those practical problems are treated, making them appear through a good synthesis of the known general theory, and vinculating them with the choice of the unknowns for any practical case. The importance of these practical problems is pointed out, and certain indications are given on how to make the best choice of unknowns to obtain results with acceptable errors and possibly with the least calculation work.

A. J. Bignoli, Argentina

2885. Franciosi, V., Some problems in statically indeterminate structures connected with prestressing (in Italian), *G. Gen. civ.* **88**, 12, 720–726, Dec. 1950.

Paper investigates effect of prestressing (by means of cables) curved statically indeterminate structures like rings and arches. In prestressed statically determinate structures, the bending moment in any cross section is given by $m = Th$, where T is the pull in the cable and h the distance measured along the section, between cable's center and centroid. If the structure becomes statically indeterminate, by introducing redundant supports, one must add to the moments m the reactive moments M_R induced by the redundant constraints.

Author shows that the diagram of the cable's ordinates h may then be divided in two parts as follows: (1) The "effective" diagram $h_E = h + M_R/T$, which does not exert any constraint at the supports; (2) the "lost" diagram $h_R = -M_R/T$, which is affine to a moment diagram induced by a system of constraints in equilibrium. This part exerts constraints on the supports, but does not change at all the state of stress in the structure.

Author studies the fundamental properties of these two diagrams. Then, he gives a procedure for calculating exactly the cable profiles for obtaining a predetermined bending moment diagram in a part of the structure. Paper ends with numerical application of this procedure to a circular ring.

Ch. Massonnet, Belgium

2886. Beaufoy, L. A., and Diwan, A. F. S., Analysis of pin-jointed redundant plane frameworks using equivalent elastic systems. *Quart. J. Mech. appl. Math.* **3**, part 1, 32–50, Mar. 1950.

2887. Lewis, S. R., The diffusion of loads in nonrigid circular frames, *Coll. Aero. Cranfield Rep.* 33, 8 pp., Feb. 1950.

2888. Bendixsen, A., The calculation of frame constructions by the method of "combined states of deformations" (in Danish), *Bygnstat. Medd.* **21**, 3, 81–116, 1950.

Statical computation of stresses in frame constructions with stiff joints is simplified considerably by introduction of certain deformations as redundants in the equations of elasticity. The advantages offered by new method comprise, partly, a considerable reduction of the number of redundants, and, partly, a very simple calculation of the coefficients in the equations of elasticity. Author introduces the so-called "combined states of deformations." These are defined in the first section, and in the following sections it is shown how, with the aid of this concept, it is possible in different ways to simplify the equations of elasticity and thus facilitate their solution considerably.

From author's summary

2889. Heyman, J., Plastic design of beams and plane frames for minimum consumption, *Quart. appl. Math.* **8**, 4, 373–381, Jan. 1951.

A solution for economical use of material in structural frames is presented. Based on the ultimate moment resistance (M_i) and the length (l_i) of each component part, the total material used is

$\alpha \sum M_i l_i$ for all the members. The determinate moment plus the indeterminate moments must be $\leq M_i$ for each member. Linear equalities for the variables are set up and solved by the Dines method, giving the moment resistance of each part for most economical material usage. Examples are given for collapse design under fixed and variable loads and shakedown design under variable loads. Irwin A. Benjamin, USA

2890. **Kriso, K., Effect of the lateral stiffness of a bridge-end frame on the calculation of buckling of a compression chord of open truss bridges** (in German), *Federhofer-Girkmann-Festschrift*, Wien, Franz Deuticke, 219–238, 1950.

A method for determining the necessary stiffness of an end frame of a truss bridge without top lateral bracing is given for a given stiffness of the intermediate frames and given sections of the elastically supported top chord. Solution of the buckling equations with determinants. Discussion of the different possible buckling cases. Numerical tables.

F. Stüssi, Switzerland

2891. **Fuxa, U., On the calculation of floor beams and on their influence on the distribution of concentrated loads between longitudinal girders of bridges in reinforced concrete** (in Italian), *G. Gen. civ.* **88**, 7–8, 442–455, July-Aug. 1950.

Torsion is taken into consideration and comparison is made with results obtained by three other Italian investigators.

George Herrmann, USA

2892. **Wierzbicki, W., Determining the factor of safety for cables of suspension bridges** (in French), *Inter. Assn. Bridge struct. Engng. Publ.* **9**, 489–494, Nov. 1949.

2893. **Cichocki, F., A new form of suspenson bridge** (in German), *Stahlbau* **20**, 1, 3–5, Jan. 1951.

Effect of arranging the suspenders at right angles to the cable is studied. A short theoretical examination of the static function of the system is carried out. Most important advantage of the suggested system seems to be the simplified details of connections between the suspenders and the cable compared with suspension bridges with vertical suspenders. The suggested system, furthermore, diminishes the bending stresses in the cable at the supports. Henrik Nylander, Sweden

2894. **Kuenzi, E. W., Effect of elevated temperatures on the strength of small specimens of sandwich construction of the aircraft type,** *U. S. Dept. Agric. Rep.* 1804, 8 pp., Aug. 1949.

Study investigates behavior of sandwich constructions at elevated temperatures up to 600 F. Tests of 21 different constructions include column compression, edgewise compression, shear, and tension normal to facings. Tests are conducted immediately after specimens reach desired temperature. Apparatus and testing methods are described and results of tests are presented.

From author's summary

2895. **Ringelstetter, L. A., Voss, A. W., and Norris, C. B., Effect of cell shape on compressive strength of hexagonal honeycomb structures,** *Nat. adv. Comm. Aero. tech. Note* 2243, 9 pp., Dec. 1950.

From results obtained with 35 test specimens of untreated 50-lb kraft paper, a family of curves was obtained by means of which it is possible to estimate specific compressive strength of such honeycomb structures within range of test data. These curves apply only when the cell walls buckle at stresses less than compressive strength of material. Test results indicate that strength of the cell changes with its shape. It appears that, within range of the seven shapes studied, strength of the structure increases with each increase in cell width, and the strongest cell is that which is widest and has the shortest walls of double thickness. The data indicate that the strongest honeycomb structure for its weight is that for which the hexagonal shape is reduced to a square by shortening the double-thickness walls until they are virtually eliminated. From authors' summary

2896. **Cicala, P., On the criterion of torsional rigidity of wing structures** (in Italian), *Termotecnica* **5**, 2, 45–49, Feb. 1951.

Proposal for two separate wing torsional stiffness criteria with regard to divergence and to reversal of aileron control. Criteria take account of principal parameters influencing these phenomena. F. J. Plantema, Holland

2897. **Heldenfels, R. R., Zender, G. W., and Libove, C., Stress and distortion analysis of a swept box beam having bulkheads perpendicular to the spars,** *Nat. adv. Comm. Aero. tech. Note* 2232, 90 pp., Nov. 1950.

Box beam is considered made up of straight carry-through section and swept outer section connected by triangular section. Outer and carry-through sections can be analyzed by known methods and problem is reduced to an analysis of triangular section satisfying equilibrium and continuity of the structure.

Vertical edges of triangular section are considered as free bodies, and equations of equilibrium are written. Due to redundancy, these equations cannot be solved directly, but authors develop force-displacement relations for each joint which, when substituted in the equilibrium equations, yield nine simultaneous equations for the displacements of the joints (one translation and two rotations for each joint). All displacements can then be determined and corresponding stresses are obtained from the force-displacement relations. Sample calculations are carried out.

Agreement with experimental data is not too good, probably because shear lag effects are neglected; however, authors indicate possible method to analyze shear lag effects.

Method takes into account flexibility of bulkheads around triangular section, and results show appreciable errors can be introduced in analysis if bulkheads are assumed rigid.

M. A. Brull, USA

2898. **Micks, W. R., Effect of torsional stiffness requirements on wing structural weight,** *J. aero. Sci.* **17**, 11, 736–740 Nov. 1950.

Curves showing weight increase of an optimum-designed stiffened sheet panel under compression due to arbitrary increase of skin thickness are given for 75S-T panel with Y-stiffeners based on the tests made by the NACA. These curves can be used conveniently for finding the added weight due to the increase of thickness required for torsional rigidity with compressive strength kept constant. Method of constructing the curves is applicable to other sheet-stiffener compression panel data.

T. H. Lin, USA

2899. **Giddings, H., Aircraft riveting,** *J. roy. aero. Soc.* 54, 480, 753–778, Dec. 1950.

Paper contains little theory but is an excellent treatise on the art of riveting. Author reviews rivet materials, types, setting procedures, and economics from viewpoint of designer. Paper is a practical survey of British techniques—essentially identical with American—applicable to aluminum-alloy structures. The contained curves illustrate author's points and provide useful bases for comparisons. They are not intended, nor are they adequate, for use in design. Joseph S. Newell, USA

2900. Williams, D., Note on the distortion characteristics of swept and cranked wings in relation to flutter and other aeroelastic phenomena, *J. roy. aero. Soc.* **55,** 482, 116–125, Feb. 1951.

Author discusses problem of determining elastic properties, as required in aeroelastic calculations of wings of unorthodox plan form having no straight flexural axis. Referring to a paper by Anderson and Houbolt [AMR **3,** Rev. 31], he explains that elementary analytical methods, still applicable, e.g., by breaking up structure in elementary box beams, will frequently not yield satisfactory results when used to calculate overtones, the reason being that the stress distribution is seriously affected by shear lag in cases of "complicated" deformation. He recommends scale-model resonance tests to obtain normal modes, and argues that, with respect to elasticity, nothing more is necessary for the purpose of flutter calculations. J. H. Greidanus, Holland

2901. Kirste, L., and Müller-Magyari, F., Stiffness and stiffness method in three-dimensional trusses (in German), *Öst. Ing.-Arch.* **4,** 5, 387–398, Nov. 1950.

Notions concerning the statics of two-dimensional trusses are developed logically for a certain class of three-dimensional trusses, which are often employed in practical design, based on the assumption of non-shifting nodes. The stiffness factor, as known for a two-dimensional node, becomes a system of six numbers, called "stiffness tensor"—being a symmetrical one—which applies to infinitesimal rotation in the space. By adopting tensorial notation, perfectly analogous relations and equations are obtained for the "carry-over stiffness" tensor, for the crippling condition of a single bar with arbitrary, three-dimensional end restraint, as well as for a continuous bar.

From authors' summary by Arturo J. Bignoli, Argentina

2902. Pirard, A., On the photoelastic study of dams (in French), *Rev. Univ. Mines* (9) 6, 12, 389–396, Dec. 1950.

Paper summarizes tests and calculations conducted to determine the distribution of stresses in all points of a gravity dam reinforced by means of cables (Coyne system). Photoelasticity techniques were used to determine the stresses produced by the hydrostatic pressure and by the reinforcing cables. No new methods are described, but paper shows an interesting application of photoelasticity to civil-engineering problems.

A. J. Durelli, USA

2903. Guerra, G., Application of photoelasticity in civil engineering (in Italian), *G. Gen. civ.* **88,** 11, 666–671, Nov. 1950.

A review of applications of photoelasticity for investigating civil-engineering structures. For statically indeterminate systems composed of beams and arches, a simple method for determining cross sections having zero bending moment and the determination of influence lines are discussed. Applications in soil mechanics are dealt with in general terms. Methods for analyzing one-dimensional or two-dimensional states of stress in reinforced concrete are treated in some detail.

F. J. Plantema, Holland

2904. Johnson, A., Calculation of deformations in reinforced concrete structures after formation of cracks (in Swedish), *Inst. Byggnadsst. Medd.* no. 6, 28 pp., 1950.

Paper treats deformation of reinforced concrete prisms in tension and deflection of reinforced concrete beams before and after cracking of concrete. Author assumes bond stress only breaks down at cracks and that bond exists between cracks. On this basis, the low deformation of tension prisms and flexed beams are accounted for by reduced stress in steel due to action of concrete between cracks in tension.

Reviewer's experience suggests assumption mentioned is not valid over whole load range to failure, and while agreeing with final results, believes they can be obtained by simpler analysis.

Frank A. Blakey, Australia

2905. Krysztal, A., Hipped plate and shell roof construction in reinforced concrete, *J. Inst. Engrs. Austral.* **22,** 10–11, 237–245, Oct.-Nov. 1950.

Author presents method of analyzing hipped-plate structures. Plates are rigidly connected along their longitudinal edges. Information on proportioning structures is given. A numerical example is worked and results compared with that of similarly dimensioned shell-roof construction. Reviewer found numerous typographical errors in equations. In computing edge loads from moments at stiff joints, author neglects force component parallel to slab. Earlier authors have made the same mistake. The method presented is approximate and much more complicated than need be. Robert B. B. Moorman, USA

2906. Barrera, E., Anelastic calculation of elements of reinforced concrete (in Spanish), *Metalurg. y Elect.* **14,** 149, 30–32, Jan. 1950.

2907. Bergström, S. G., Temperature stresses in concrete pavements, *Sven. Forskninginst. Cement Betong,* 37 pp., 1950.

2908. Davis, E. H., The California bearing ratio method for the design of flexible roads and runways, *Géotechnique Lond.* 1, 4, 249–263, Dec. 1949.

2909. Bergström, S. G., Fromén, E., and Linderholm, S. Investigation of wheel load stresses in concrete pavements, *Sven. Forskninginst. Cement Betong Handl.* no. 13, 162 pp., 1949.

2910. Fornerod, M., Factors in prestressed girder design, *J. Amer. Concr. Inst.* **22,** 6, 469–480, Feb. 1951.

Article describes design and construction of the first prestressed concrete bridge in U.S. Belgian system of post tensioning is used in applying prestress. Bridge consists of simply supported girders of 160-ft span. Stresses in the beam are given for the various loads which come on to the beam during construction. Transverse prestressing cables through stiffening webs between the girders are used as well as longitudinal prestressing cables in the girders themselves. Transverse bending of stiffeners is calculated, assuming they act as beam on elastic foundation.

Frank A. Blakey, Australia

2911. Layrangues, Calculation of stresses in a symmetrical arch with supports in one plane under influence of horizontal forces situated in the plane of the neutral axis (in French), *Ann. Ponts Chauss.* **120,** 6, 637–667, Nov.-Dec. 1950.

Until recently, the analysis of arches has been restricted generally to vertical loads, and the effect of horizontal loads (such as breaking trains) had not been determined theoretically with precision. Author has derived expressions for direct and shearing forces and bending moments in two-hinged and fixed arches subjected to horizontal loads.

With one exception, analytical results are restricted to parabolic arches, which is unfortunate in view of the frequent use of circular shapes in practice. On the other hand, a variable moment of inertia of the members is considered, and the treatment is enhanced by representing most results in the form of influence lines and illustrating their use by numerical examples.

G. G. Meyerhof, England

2912. **Velutini, B., Analysis of continuous circular curved beams,** *J. Amer. Concr. Inst.* **22,** 3, 217–228, Nov. 1950.

This type of problem is important not only in bridge girders but still more so when architectural treatment calls for a circular façade to a building. The Hardy Cross method of moment and torque distribution gives remarkably quick convergence in the case in question. Reviewer feels that, with corrections to torques due to distributing moments being several times as great as the fixed-end torques themselves, quick convergence may not be the general rule.

The general expressions for stiffness factors, etc. (bottom page 221) should, in the interest of clarity, be multiplied by appropriate quantities, i.e., Sm by EI/r, etc. Some numerical errors, including one transposition of figures, occur on page 227 above fig. 6. A. H. Finlay, Canada

Rheology (Plastic, Viscoplastic Flow)

See also Revs. 2820, 2871, 2876, 2954, 2966, 2967, 2985, 3041, 3042

2913. **Il'yushin, A. A., Plasticity. Part one. Elastic-plastic deformations. [Plastichnost. Chast pervaya. Uprugo-plasticheskiye deformatsii],** Moscow-Leningrad, OGIZ, 1948, 376 pp.

Fundamental laws of elastic-plastic deformation. Fundamental equations of the theory of small elastic-plastic deformations. The simplest problems of the theory of plasticity. Equilibrium of plates and shells. Stability of plates and shells. The pressing in of dies and the supporting capacity of an incompressible plastic body. Dynamical problems of plasticity.

Courtesy of Mathematical Reviews Table of contents

2914. **Hodge, P. G., Jr., The method of characteristics applied to problems of steady motion in plane plastic stress,** *Quart. appl. Math.* **8,** 4, 381–386, Jan. 1951.

Problem of stress and strain distribution in a thin sheet strained plastically in its plane requires, in the case of steady motion, solution of a system of the following six equations: Two equations of equilibrium, one for the yield condition, one for incompressibility of the material, and two for the plastic potential stress-strain law. The system is transformed into a set of five quasilinear first-order differential equations. To find the characteristics, a 10×10 determinant must vanish. This can be reduced to a product of one 2×2 and two 4×4 determinants which supply the first and second characteristics and the streamlines. Conditions for velocity, and the stress relations along the characteristics are stated. To obtain numerical solutions of boundary-value problems, the differential equations must be replaced by finite difference equations. For the general case of nonsteady motion a step-by-step procedure is indicated briefly.

H. Kauderer, Germany

2915. **Hodgdon, F. B., Stuart, D. A., and Bjorklund, F. E., The application of rate-process theory to glass. I. Breaking strength, II. Viscosity,** *J. appl. Phys.* **21,** 11, 1156–1170, Nov. 1950.

A general equation relating the ultimate strength of ceramics to time under load is derived. Fundamental is the rate-process theory produced by H. Eyring, who has pointed out that, in all unit processes of deformation, stress produces a two-fold influence on rate of strain. First there is an elastic component for which strain and stress behave linearly, and secondly there must be a contribution to the rate of strain by relaxation process. The latter is well-known for molecular and crystallic materials but rather unknown for ceramics. How to find out this relationship is carefully treated and the deduced theory seems to give good agreement with experimental results. The main point is that failure in ceramics must always be failure in tension. Qualitatively, the brittle breaking of glass can be explained by the obtained results. As to the viscosity problem of glass, some rather confusing remarks are made. Theoretically, it is obvious that the equation relating viscosity dependence on time and temperature can be closely defined and calculated from the chemical composition; but practically, it is shown that a very little alteration of chemical composition must give essential errors in the calculated data of viscosity. Perhaps this anomaly could be explained by formal errors in the viscosity functions.

Ragnar Nilson, Sweden

2916. **Bijlaard, P. P., The foundations of the mathematical theory of plasticity and the test** (in German), *Z. angew. Math. Phys.* **2,** 2, 114–117, Mar. 1951.

Note on a paper under same title reviewed in AMR **4**, Rev. 1147.

2917. **Lee, E. H., On stress discontinuities in plane plastic flow,** *Proc. Symp. appl. Math.* **3,** 213–228, 1950.

Paper concerns the application of the ideal plastic analysis to problems in plane strain in which a surface of stress discontinuity is involved. It shows that it is not sufficient to satisfy the equations of equilibrium and plastic flow, but, in addition, the equations governing the velocities of flow must also be considered. Plastic flow in an acute-angled wedge with uniform pressure on one face is considered to illustrate the importance of the velocity conditions. M. C. Shaw, USA

2918. **Wood, W. A., and Scrutton, R. F., Mechanism of primary creep in metals,** *J. Inst. Metals* **77,** 5, 423–434, 1950.

Reports creep tests of high purity aluminum at 290 C. Apparatus permitted back-reflection x-ray and microscopic examination of the specimen at will during the test. Authors' interpretation of observations provides no evidence to support the view that a running balance exists between disordering and recovery. The process of dissociation of grains into a substructure appeared to the authors to be associated with primary creep. At high rates of deformation this dissociation is accompanied by a disordering of the structure (presumably at the boundaries of the substructure) which is then removed on continued deformation, leaving the substructure. This two-stage recovery mechanism produces a progressive softening. At slower rates, the dissociation proceeds directly, unaccompanied by a disordering. This "cell" mechanism produces a progressive hardening of annealed material. The primary creep curve is regarded by the authors as the resultant of the two mechanisms.

William N. Findley, USA

2919. **Marin, J., and Hu, L. W., Interpretation of tension creep-time relations,** *Amer. Soc. Test. Mat. Bull.*, no. 171, 57–59, Jan. 1951.

Authors suggest power-function relation for both intercept and secondary creep rate in constant-load creep tests giving equation for creep strain of the form $\epsilon = DS^m + BS^n t$ (S stress, t time). Using method of least squares, values of constants D, m, B, and n are determined for seven different materials from data given in ASME-ASTM Creep Data Book (1938). Log-log plots indicate that, for these materials, proposed power-function relation will yield satisfactory approximation within range covered by tests. Although power-function expressions are simpler, note that when extrapolating from test stresses to lower stresses, as used in service, relations of the hyperbolic sine form (also used fre-

quently) will, in general, yield higher strain values than those given by power-function law, i.e., are more conservative for design.

A. M. Wahl, USA

2920. Reiner, M., The rheological aspect of hydrodynamics, *Quart. appl. Math.* **8, 4,** 341–349, Jan. 1951.

Paper extends concept of volume viscosity presented in author's two recent books (AMR 4, Revs. 1158, 1159). It is shown that theory and experiments on viscous fluids can be made to agree if the coefficient of volume viscosity is very much larger than the ordinary (shear) coefficient of viscosity and not necessarily equal to zero, as Stokes has claimed. General relations between stress and rate of deformation indicate the presence of five coefficients. These are the coefficients of shear viscosity, volume viscosity and of dilatancy, and one coefficient may be connected with the "Weissenberg effect." It is shown that if volume viscosity is neglected, then the Navier-Stokes equations may be used consistently only for incompressible liquids.

H. H. Hilton, USA

2921. Mardles, E. W. J., and de Waele, A., Some aspects of the rheology and the stability of emulsions and suspensions, *J. Colloid Sci.* **6,** 1, 42–56, Feb. 1951.

Influence of properties of surface films adsorbed on the dispersed particles is considered. Small amounts of a suitable soluble substance which becomes adsorbed at the interface increases stability and changes rheological behavior of the system as, e.g., sedimentation volume. With creams, greases, or pastes, and when dispersed particles are in close proximity, effect of surface film on friction and adhesion between particles outweighs effects directly due to viscosity and density differences. Generally in highly concentrated systems this aspect outweighs the hydrodynamic approach, and explains independence of viscosity of concentrated dispersions of the viscosity of the dispersing medium or the temperature. A moving plate viscometer was used in which a loaded plate falls freely edge-on in a vertical guide. The surface effect was traced in $^1/_{16}$-in. diam steel balls where the sedimentation volume in different liquids decreases as the static friction and/or the angle of repose.

M. Reiner, Israel

2922. Eccher, S., Rheometric tests and extrusion, *Indust. Engng. Chem.* **43,** 2, 479–487, Feb. 1951.

Natural and synthetic rubbers with various fillers were tested in a Couette-type rheometer (concentric cylinders with relative rotation and annulus of test material). Over shear-rate range 1 to 100 inverse seconds, a linear log (shear-rate)–log (shear stress) relation is obtained. Theoretical pressure variation for laminar flow down cylindrical pipe is given, velocity profile being function of the gradient of the linear relation mentioned above. Extrusion down a cylindrical pipe checks the theory satisfactorily. Extrusion through more complicated system gives less satisfactory agreement.

E. H. Lee, USA

2923. Harper, R., and Baron, M., The application of factor analysis to tests on cheese, *Brit. J. appl. Phys.* **2,** 2, 35–41, Feb. 1951.

Paper discusses that, through "factor analysis," if a number of objects undergo a number of tests A, B, C, . . . in which scores or measurements a_i, b_i, c_i, . . . are allotted to the i-th object, correlations may be found to exist between the scores in various pairs of tests. The correlation expresses extent to which any two tests measure the same "factor."

Technique is applied to study of the relationship between a number of rheological tests and essential subjective judgments on cheese. Two studies on groups of about 200 cheeses made in successive seasons show that measurements of surface hardness through indentation by a loaded sphere and subjectively assessed crumbliness may be closely correlated. The remaining factors are found too complex in origin for correlation, as it depended on arbitrary grouping in the tests and assessments selected.

Dimitri Kececioglu, USA

2924. Lethersich, W., Apparatus for the study of creep of dielectric polymers and their dynamic rheological properties, *J. sci. Instrum.* **27,** 11, 303–306, Nov. 1950.

Apparatus is described for applying a shear stress rapidly to solid materials and for measuring the strain a few milliseconds afterwards. Apparatus can also be used for measuring the dynamic modulus and internal friction coefficient over a range of frequency from 30 to 1000 c/s; a modified form enables the frequency range to be extended down to 10^{-4} c/s.

From author's summary by Stacey G. Ward, England

2925. Yagn, Yu. I., and Tarasenko, E. N., Applied theory of plastic deformation of shafts (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)*, **73,** 3, 471–474, July 1950.

Authors assume strain distribution given essentially by Eqs. (18) of Love's "Elasticity," 4th ed., p. 392, with $\zeta = \tau(s)\phi(x,y)$, ϕ = torsion function. They adopt "deformation" theory of plasticity [cf. Prager, AMR **1,** Rev. 1122], with zero volume change; thus, stresses are related to strains by use of secant shear modulus which is function of octahedral shear strain. By inserting stress-strain relations in formulas for longitudinal force and bending and twisting couples exerted across section, they relate these quantities to elongation, curvatures, and twist. Nontorsional terms in e_{zx} and e_{yz} are retained in some formulas, neglected in others, and ultimately eliminated by use of an auxiliary equilibrium equation involving "bimoments" of applied forces and of tractions. Final equations for general case are intractable; two special cases are considered which, for symmetric sections and for parabolic stress-strain law, lead to sets of equations capable of numerical or graphical treatment. It is not clear to reviewer what quantities are supposed given and what quantities are to be found; which of several omitted equations (such as ordinary equilibrium relations among forces and couples) are to be used, and which ignored; nor what approximations are involved in the auxiliary equilibrium equation.

William Fuller Brown, Jr., USA

2926. Mooney, M., and Black, S. A., Elongation hysteresis of Hevea and synthetic elastomers, *Canad. J. Res. Sec. F.* **28,** 4, 83–100, Apr. 1950.

Using an ingenious instrument termed a "spider hysterometer" (U. S. Patent 1,595,318, Shields, 1926) direct measurements were made of the energy loss per cycle of elongation in certain commercial elastomers. Six samples positioned like spokes of a wheel are stretched to various mean initial elongations between a small disk (hub) and a large disk (rim). The rim is motor-driven and the hub, mounted in a ball bearing, is displaced eccentrically with respect to the rim. In the straining cycle which each sample undergoes from some minimum arbitrary extension to some maximum arbitrary extension, the hysteresis gives rise to average force on the hub which is proportional to the energy loss per cycle of rim rotation. A level and balance system using special low-friction air bearings makes it possible to measure the hysteresis force while the rim is turning. Measurements were made on T-50 specimens, die cut from $^1/_{10}$-in. sheet Hevea, GR-S, Butyl, Hycar, Perbunan and Neoprene gum sticks. Absolute hysteresis coefficient, defined as the ratio of energy loss per cycle to the product of specimen

volume, and the square amplitude of strain cycle were obtained as a function of mean initial elongation of the six specimens. These data indicated for all stocks that the absolute hysteresis decreased as function of mean initial elongation except the crystalline stock, which initially decreased, then increased with larger strains. The hysteresis decreased slightly as a function of strain amplitude for all stocks, increased with frequency between 2 and 60 cps, and decreased as a function of temperature. A simple theory for the measurement of a "differential modulus" by means of the instrument is given and measurements presented which have dependencies on mean initial strain which first decrease then increase as the strain increases. This modulus decreases as the strain amplitude increases; is comparatively unaffected by frequency changes between 2 and 60 cps, and decreases with temperature except in Hycar and Perbunan at low initial extensions and Hevea at low strain amplitudes. The "relative hysteresis" (proportional to the log dec) is defined as the ratio of "absolute" hysteresis to the differential modulus. The dependency of the relative hysteresis on the independent variables of the study is similar to that given above for the absolute hysteresis. All the data suggest that the absolute hysteresis increases as temperature of the test approaches the second-order transition temperature of the various stocks used; and roughly follows a common trend when plotted as a function of temperature of test minus the second-order transition temperature for the respective stocks. This suggests to authors that the mechanisms leading to this tensile hysteresis in the stocks studied are related to those which develop "brittleness" as the temperature is reduced to the second-order transition temperature. Certain departures from this observation were noted for Hevea and Butyl stocks. W. George, USA

2927. **Swida, W., On the elasto-plastic deformations of a plate** (in German), *Z. angew. Math. Mech.* **30,** 8/9, 246–247, Aug.-Sept. 1950.

Paper gives (without derivation) two equations between deflection of plate and depth of the plastic zone. Von Mises' yield condition is used, but the type of stress-strain law is not specified, although the form of the equations suggests that deformation theory has been applied. W. T. Koiter, Holland

2928. **Aust, K. T., and Chalmers, B., Surface energy and structure of crystal boundaries in metals,** *Proc. roy. Soc. Lond. Ser. A,* **204,** 1078, 359–366, Dec. 1950.

Object of present investigation is to determine whether the boundary between two crystals of relatively pure lead could be assumed to be made up of a "transitional lattice" or of an "amorphous cement." If former is true, the amount of surface energy associated with the boundary will depend upon the amount of misfit between the lattices of the two adjoining crystals. If latter is correct, the surface energy should not depend upon the orientation of the two crystals. Experimental evidence is given to show that the surface energy does vary with the amount of misfit between the lattices.

It is shown how such a transitional lattice might be made up of a certain grouping of dislocations, the energy of which could be calculated. The measured energies compare favorably with these calculated values. Evan A. Davis, USA

2929. **Marin, J., and Kotalik, B. J., Plastic biaxial stress-strain relations for Alcoa 24S-T subjected to variable-stress ratios,** *J. appl. Mech.* **17,** 4, 372–376, Dec. 1950.

Paper presents biaxial plastic stress-strain relations for both constant- and variable-stress ratios Purpose of conducting the variable-stress-ratio tests is to attempt to prove whether the flow- or deformation-type theory is the correct theory for predicting plastic stress-strain relations. Paper also gives a comparison between the actual and theoretically predicted values of biaxial yield, ultimate and fracture strengths, and the biaxial ductility. Various ratios of biaxial tensile stresses were investigated by subjecting tubular specimens to axial tension and internal pressure. Test results show that the yield-strength values agree best with the distortion-energy theory. For prediction of plastic stress-strain relations, the deformation-type theory was found to be in approximate agreement with the test results for both the constant- and variable-stress-ratio tests.

From authors' summary

Failure, Mechanics of Solid State

(See also Revs. 2829, 2915, 2942, 2964, 2968)

2930. **Campbell, W. R., Stress studies of welded ship structure specimens,** *Weld. Res. Suppl.* **16,** 2, 68s–76s, Feb. 1951.

Results are reported on static tension tests of four interrupted ship steel specimens of different design, simulating structural details of welded tankers, namely, intersection of a bottom longitudinal and a transverse bulkhead.

Elastic stress distribution at room temperature, maximum load, strain distribution prior to fracture, and energy to fracture at 0 F were determined. George V. Smith, USA

2931. **Vedeler, G., Brittle fracture in ship plate,** *Engineering* **170,** 4419, 290–291, Oct. 1950.

Brief letter contribution suggesting relations for calculating the ratio of ultimate strength to yield point as function of principal stress ratios and stress-concentration factors. To be used with chart previously presented for predicting danger of brittle fracture. Henry A. Lepper, Jr., USA

2932. **Wiegand, H., Size and fatigue strength with reference to the material** (in German), *Z. Ver. dtsch. Ing.* **93,** 4, 89–91, Feb. 1951.

Fatigue strength of components cannot be ascertained from fatigue strength of metal specimens tested under uniform stress. Composition, production, and heat treatment of material must be considered in conjunction with shape and dimensions. Size effect is apparent only in presence of stress gradient. Author quotes results obtained by Hempel, who found no size effect in fatigue tensile tests with round alloy steel specimens of 15- to 30-mm diam. Buchman found no size effect with smooth electron specimens of 5 to 20 mm. Author found size effect in bending- and torsion-fatigue tests on Cr-Ni-W steel with unnotched, smooth specimens as well as specimens with transverse hole if specimen diameter increased from 5 to 30 mm for bending and from 15 to 35 mm for torsion. No significant further decrease in fatigue strength for larger diameters. Cause of decrease is decrease of stress gradient, but author fails to distinguish stress-concentration factor and stress gradient as independent variables.

Results of alternating torsion-fatigue tests with Cr-Ni-W steel—solid round and tubular specimens—are quoted for different surface conditions. Fatigue strength diminishes from ±35 kg/mm² for polished solid round of 15 mm diam to ±25 kg/mm for 60 mm O/D tube, heat-treated, surface-machined; to ±20 kg/mm for butt-welded, weld-machined, not heat-treated tube of same diameter.

Author stresses importance of composition, heat treatment, etc., but fails to give details of either composition, heat treatment, or welding process of his test pieces beyond stating that tensile strength was 90 kg/mm². R. Week, England

Material Test Techniques

(See also Revs. 2787, 2839, 2841, 2855, 2880, 2924, 2943, 2959, 2961)

2933. Prot, M., A new technique for testing of cement, mortar and concrete. Simple tension tests on prismatic or cylindrical test bars (in French), *Rev. Matér. Constr.*, no. 426, 69–76, Mar. 1951.

Author suggests that tensile strength of cement, mortars, and concretes be determined on cylindrical specimens of the same size as those used for determination of the compressive strength. To hold the specimens in the testing machine, heads with rubber inserts were developed, transmitting the load by friction. Author claims that specimens seldom break inside the heads, and that the load is transmitted without eccentricity.

Reviewer thinks that some of the incidental considerations about "intrinsic curves" oversimplify the failure phenomenon. No mention is made, for instance, of the influence of the second principal stress on failure. A. J. Durelli, USA

2934. Henrion, E., Development of impact test methods for materials used in metallic constructions (in French), *Ossature métallique* **15**, 12, 567–576, Dec. 1950.

Author discusses impact tests on metals and suggests use of H. M. Schnadt's theory and experimental methods [*Welding*, July 1950, p. 313]. Theory depends on the concept of "plastifying power" π, which is claimed to measure influence of a combination of stresses on plasticity. Neither Schnadt nor present paper states how expression for π is derived. Impact tests with different types of notched specimens are discussed and author states these may be correlated with behavior under practical conditions.

H. Kolsky, England

2935. Frisch, D. H., and Levin, J. S., A mechanical wear test using fission fragments, *Amer. Soc. Test. Mat. Bull.* no. 172, 64–65, Feb. 1951.

Paper describes the experimental test of a radioactive measurement of wear. Radioactivity is induced on the surface of a sample by a bombardment of fission fragments being ejected from a Uranium-235 foil by neutrons of a radium-beryllium source. The activity depth can be changed by varying distance between the sample and the uranium foil. The wear depth is determined by comparing the counts of a counter caused by the worn sample with those of a not worn sample which has been exposed to the bombardment in the same manner.

Authors proved the procedure by comparing its results with depth-measurements by standard gage blocks. The method permits measurements of wear depths in a range from 10^{-6} to 10^{-4} in. of dense materials and up to a mil of lighter materials. A folding-under of the outer layers of metal effected by the friction makes dubious the industrial application of the method, especially if the worn surface gets hot. Ulrich Rost, Germany

2936. Brenner, A., Microhardness tester for metals at elevated temperatures, *J. Res. nat. Bur. Stands.* **46**, 2, 126–131, Feb. 1951.

An apparatus has been devised for measuring the hardness of electrodeposited coatings at temperatures up to 900 C in an inert atmosphere. Coatings thicker than about 0.07 mm (0.003 in.) may be tested. Main parts of the apparatus are: (1) The indenting mechanism, consisting of a Vickers diamond mounted on a shaft of fused silica; (2) a mechanical device for raising and lowering the indenter; (3) a micrometer device for orienting the specimen under the indenter; and (4) the heating unit. The force on the indenter is varied either by dead-weight loading or by changing the gas pressure inside the apparatus. Some typical measurements made with the apparatus are given.

From author's summary by B. L. Wilson, USA

2937. Krautkrämer, J., and Krautkrämer, H., An ultrasonic apparatus for nondestructive testing of materials (in German), *Arch. Eisenhüttenw.* **20**, 11/12, 355–358, Nov.-Dec. 1949.

2938. Fischer, E., Pressure measurements with metallic test bodies (in German), *Z. Ver. dtsch. Ing.* **93**, 2, 37–40, Jan. 1951.

A method is described for measuring the peak values of forces, which involves permitting the unknown force to act on a metallic bar of such size and characteristics that plastic flow of the bar will occur under action of the force to be measured. The bar is then placed in a testing machine and its resistance to further plastic deformation is measured. It is assumed that the load at which plastic flow begins upon reloading corresponds to the peak value of the force whose magnitude is desired. Selection of suitable materials for weigh bars and limitations of the method are discussed. W. T. Lankford, USA

Mechanical Properties of Specific Materials

(See also Revs. 2790, 2879, 2894, 2901, 2915, 2919, 2926, 2929, 2931, 2932, 2933)

2939. Heyer, R. H., Effect of speed of testing on the tensile properties of austenitic stainless steel sheets, *Amer. Soc. Test. Mat. Bull.* nos. 158, 162; 57–62, 53–55; May, Dec. 1949.

2940. Smith, H. E., and Cox, H. L., A note on the tensile strength and elongation of wide plates of aluminum alloy with and without holes, *Aero. Res. Counc. Lond. Rep. Mem.* 2429, 8 pp., Aug. 1944, publ. 1951.

Tensile tests have been made on plates 10 in. and 13 in. wide cut from sheets of 16, 20, and 24 s.w.g. The series of test pieces comprised one set plain without holes; one set with a 3-in. diam hole in the middle of the test length; one set with the same hole reinforced at the edge by a cover ring riveted on; and three sets with the hole reinforced by pressed flanges of three different depths.

Presence of the hole reduces tensile strength of the sheet in the transverse section through the hole only slightly, and the reduction is not appreciably affected by reinforcing the hole. Reinforcement has, however, a considerable effect in reducing cross buckling of the sheet above and below the hole under the compressive stress developed in these regions, and, in this respect, pressed flanges are not inferior to stiffening rings. The behavior of wide plates under static tension does not differ materially from the behavior of the usual narrow test pieces.

From authors' summary

2941. McKeown, J., and Lushey, R. D. S., Creep properties of some aluminum alloys at temperatures up to 300° C., *Metallurgia, Manchr.* **43**, 255, 15–19, Jan. 1951.

2942. Smith, F. C., Brueggeman, W. C., and Harwell, R. H., Comparison of fatigue strengths of bare and Alclad 24S-T3 aluminum-alloy sheet specimens tested at 12 and 1000 cycles per minute, *Nat. adv. Comm. Aero. tech. Note* 2231, 18 pp., Dec. 1950.

Report describes results of axial fatigue tests conducted on 0.032-in.-thick flat-sheet specimens of bare and Alclad 24S-T3 aluminum alloy to determine effect of frequency of loading on fatigue strengths of these materials. Number of cycles to failure

varied from about 150 to over 10,000,000. Tests were conducted using completely reversed axial load at two frequencies of loading: 12 and 1000 cpm. Tests showed that fatigue strengths of the materials were slightly less when tested at 12 cpm. For those specimens which were stressed into the plastic range, an investigation was made of the variation of maximum stresses and mean stresses with repeated loading. From authors' summary

2943. **Nicol, A., Bibliographic survey of the causes of concrete corrosion** (in French), *Rev. Matér. Constr.* no. 414, 65–84, Mar. 1950.

The subject is divided into the following divisions: Effect of (1) aggregates (alkali reaction), (2) gel (expansion), (3) fire, (4) water, (5) gases, and (6) organic compounds.

Article concludes with discussions of means of preserving concrete and new cements. Its chief advantage lies in its extensive bibliography, which is well organized.

Frank J. Mehringer, USA

2944. **Scholer, C. H., A wetting-and-drying test for predicting cement-aggregate reaction,** *Proc. Amer. Soc. Test. Mat.* **49,** 942–953, 1949.

2945. **Jones, R., Elasticity and rupture of concrete and stone at constant rates of loading,** *Nature* **165,** 4184, 39–40, Jan. 1950.

2946. **Bergström, S. G., and Linderholm, S., Vibration of concrete** (in French), *Sven. Forskninginst. Cement Betong. Medd.* no. 18, 80 pp., 1949.

2947. **Voss, A. W., Norris, C. B., and Palma, Joseph, Jr., Buckling of flat plywood plates in uniform shear with face grain at angles of 0°, ±45°, and 90°,** *For. Prod. Lab. Rep.*, no. 1316-H, revised, 16 pp., July 1950.

In this revision of a 1945 report, buckling and ultimate strengths of several hundred specimens are tabulated and plotted. Buckling strengths coordinate fairly well with previous theory. Ultimate strengths are coordinated with results from a "coupon," or small panel similarly tested, but many misprints confuse the presentation. Shear was applied through a parallelogram jig having strong wooden sides glued to the panel edges; moderate variation in stiffness of jig sides produced no consistent effect.

L. H. Donnell, USA

2948. **Kollmann, F., Theoretical and practical problems in drying wood** (in German), *Sven. TräforskInst. Medd.* 11 B, 11 pp., 1949.

Referring to recent theoretical investigations, especially those by A. J. Stamm, the analytical theories for drying wood are described. Although it has been possible to compute the diffusion of moisture in wood and to show that the theoretical values agree surprisingly well with test data accumulated by various investigators, at this time only information based on actual field observations and proved experience makes possible satisfactory and economical drying of wood.

A short review of the required drying equipment is presented, which gives emphasis to proper arrangement to ascertain uniform air currents in the dry kilns. Drying in a high-frequency field and under vacuum is discussed. Artificially putting the drying lumber into motion on a swing or on a turntable is mentioned as a possibility to accelerate air-seasoning.

Additional research on seasoning and drying wood is suggested, especially since, under given conditions, the cost of drying wood approaches the original cost of green wood. E. G. Stern, USA

2949. **Alexander, J. B., The physical and mechanical properties of second-growth Douglas Fir,** *Amer. Soc. Test. Mat. Bull.* no. 169, 33–38, Oct. 1950.

Data are presented for one shipment of seven logs, 60-yr age class; one shipment of seven logs, 90-yr age class; partial data for the species, virgin growth; partial data for one shipment of poles, 30-yr age class; one shipment of poles, 60-yr age class; and for one virgin-growth Douglas fir tree tested over its full commercial length of 152 ft in 4-ft sections.

From author's summary

2950. **Bachman, G. B., Filar, L. J., Finholt, R. W., Heisey, L. V., Hellman, H. M., Lewis, L. L., and Micucci, D. D., Properties of new synthetic rubbers and plastics,** *Indust. Engng. Chem.* **43,** 4, 997–1002, Apr. 1951.

A large number of new copolymers of the thermoplastic type have been prepared and physical properties studied. A new method of determining refractive index of transparent solids has been developed. A new property of plastics—the "sticking point"—is defined and a method proposed for measuring it conveniently. From authors' summary

2951. **Dauphinee, T. M., Ivey, D. G., and Smith, H. D., The thermal conductivity of elastomers under stretch and at low temperatures,** *Canad. J. Res. Sec. A.* **28,** 6, 596–615, Nov. 1950.

Heat conductivity of natural rubber and GR-S was studied in the range from +50 C to −170 C and from 0 to 100% stretch. Apparatus used was a greatly modified version of one designed by Schallamach. Conductivity of both types of rubber at 0% stretch lies in range between 3.5×10^{-4} and 4.0×10^{-4} cal/sec cm deg C. Stretching increases rate of change conductivity with temperature of both natural rubber and GR-S, and decreases conductivity of latter. On lowering temperature and raising it again, natural rubber exhibits a complicated hysteresis phenomenon, while GR-S shows a hysteresis loop caused by a second-order transition near the brittle point. Hysteresis phenomena of both types of rubber near the second-order transition temperature show considerable similarity to changes in specific heat observed by Bekkedahl and co-workers. Above and below the transition region, heat conductivity decreases approximately linearly with temperature, as might be expected from classical theory. The variation through the second-order transition does not agree with classical theory, but may be explained qualitatively on the basis of a diffuse lambda-type transition.

From authors' summary

2952. **Pfalzner, P. M., On the friction of various synthetic and natural rubbers on ice,** *Canad. J. Res. Sec. F.* **28,** 12, 468–489, Dec. 1950.

Paper presents experimentally determined values of friction between ice and shoes of natural and synthetic rubber sliding on the ice. The ice is a coating on a rotating turntable; the shoes are held against the ice by calibrated springs. The effects of rubber hardness, ice temperature, and extraction of the rubber on the friction were measured. Data are also given showing the relation of temperature, age, and resilience of the rubber to its hardness. Charles E. Crede, USA

2953. **Zapp, R. L., and Guth, E., Elastic modulus and swelling of butyl vulcanizates,** *Indust. Engng. Chem.* **43,** 2, 430–438, Feb. 1951.

Reinforcement of butyl rubber was studied by measuring the increase in elastic modulus as carbon black or inorganic fillers were added to the rubber. Butyl rubber was chosen in order to

keep the concentration of cross links constant. Reinforcement action can be split into two parts—a volume effect and a surface effect of the pigment or filler. Volume effect is independent of particle size of the pigment. The surface or adsorption part increases with a decrease in particle size. All pigments show the volume effect, but only carbon black shows a strong surface effect. Bonds between the rubber and carbon black behave as additional cross links, and are strong enough to persist even in the presence of solvents and prevent the filled rubber from swelling to as large a volume as an unfilled rubber. These results emphasize the unique position held by carbon blacks in the field of rubber reinforcement. Lawrence Nielsen, USA

2954. Kauffman, J., and Waller, G., Load induced X-ray line broadening in nylon filaments, *J. appl. Phys.* **21,** 5, 431–434, May 1950.

Paper describes a portion of a general research directed toward an understanding of the micromechanisms of plastic flowing in crystalline high polymers. X-ray diffraction was used for the study, and the material chosen was a strong, highly oriented, crystalline nylon fiber. The fibers were received as 100 denier monofilaments.

The load-induced microscopic structural changes in highly oriented nylon filaments were followed by changes in the x-ray fiber diffraction pattern as a function of the resulting strain. Observations made included (1) changes in the dimensions of the fiber spots, and (2) a decrease in ratio of the intensity of amorphous to crystalline x-ray scattering. These new results for Type 200 du Pont nylon indicate a change in the microdeformation mechanism at a strain corresponding to the inflection of the load-strain diagram (14% elongation). The mechanism for smaller plastic strains appears to involve a rotation of the crystallized domains into alignment with the fiber axis, accompanied by a small overall additional crystallization. For strains larger than the inflectional strain, the mechanism seems to involve a progressive reduction in the domain size, and a reduction in alignment with the fiber axis. Both effects appear to saturate in the vicinity of the rupture strain. These results are discussed in terms of load-induced effects found in metal single and polycrystals. It is suggested that the qualitative features observed may be representative of a wide class of load- or strain-induced microdeformation reactions in the solid state. From authors' summary

2955. Davis, E., and Holmes, E., The pressure-welding characteristics of some copper-base alloys, *J. Inst. Metals* **77,** part 3, 185–206, 1950.

Pressure-welding characteristics of deoxidized copper and nine commercial copper-base alloys have been determined by making butt welds with $^1/_2$-in. or $^5/_8$-in. diam rod, the efficiency of jointing being assessed by tensile testing and micro-examination. Heating to welding temperature was effected by means of an oxyacetylene ring burner, and pressure was applied by a hydraulic press of 10 tons capacity. The joint strength was influenced by the surface condition before welding, mechanical preparation proving most suitable, and by the deformation taking place during welding. Welding time, pressure, and temperature were of importance only in so far as they affected deformation, provided that the welding temperature exceeded the recrystallization temperature of the material. With each alloy welded, joints were made of a strength equal to the inherent strength of the annealed material, and welding took place by recrystallization across the interface. Taking as the criterion of weldability the minimum deformation required to produce maximum joint strength, the order of merit was: deoxidized copper; 70:30 and 80:20 cupro-nickel; 93:7 and 91:9 phosphor bronze; 85:15 brass; α/β brasses; silicon bronze, and aluminum bronze. From authors' summary

2956. Campus, F., Influence of length on transverse shrinkage of butt welds (in French), *C. R. Acad. Sci. Paris* 232, 9, 792–794, Feb. 1951.

Transverse shrinkage of butt welds per unit of mean width of joint preparation is proportional to heat input. If length increases by dl, heat input increases by Adl. If work for incremental shrinkage $d\rho$ is $Bld\rho$, where l is length of joint already welded, and if this is proportional to heat input: $Adl = Bld\rho$ and $\rho = \rho_1 + k \log l$. Shrinkage is therefore logarithmic function of joint length. Measurement of transverse shrinkage over 48-mm gage length along welds varying from 10 mm to 2000 mm in length in plates 15 mm thick and 300 mm wide are claimed to agree with logarithmic law. Scatter of experimental results is ±31%. Measurements carried out on joints 6000 mm long in shipyard during tanker construction claimed to be in good agreement with new formula which gives smaller values than previous formulas by Wortmann and Mohr, or Malisius who neglected effect of length.

Reviewer believes effect of length to be chiefly effect of starting and finishing weld when heat flow can take place only in radial direction of semicircle. This effect therefore is noticeable only for short joint lengths, say up to 150 mm. Average shrinkage of longer joints reasonably independent of length, and author's results for joint longer than 150 mm are almost constant, taking account of large scatter. Logarithmic law in any case would require infinite shrinkage for joints infinitely long. Author's results for 600-mm long joints are not larger than those obtained for joints 2000 mm long so that these provide no evidence for increase of shrinkage with increase in length. In reviewer's opinion, theoretical derivation of logarithmic law as quoted is not tenable either. R. Weck, England

2957. Fukui, S., Kubo, H., and Senio, J., On the Vickers hardness number under light testing loads (in Japanese), *Rep. Inst. Sci. Technol. Tokyo* **4,** 7–8, 204–210, July-Aug. 1950.

Influence of surface finishing process of specimen upon the Vickers hardness number, measured under light testing load down to 1 kg, was studied for aluminum, duralumin, copper, brass, mild steel and 13% Cr steel. The hardness of electro-polished surface was independent of testing load used, but slight hardening was observed on the surfaces finished by fine emery paper or buffing. More evident hardening was revealed on machined surface. Moreover, the relation between hardness number and testing load was examined when the shape of diamond pyramid was roof type. In this case, the apparent hardness number decreased with lighter load. From authors' summary

2958. Keating, F. H., and Mathias, E. V., The use of mild steel for service at subzero temperatures, *Instn. mech. Eng. appl. Mech. Proc.* (*W.E.P.* no. 55) **163,** 27–40, 1950.

Paper describes an investigation undertaken to determine the limiting subzero temperature at which mild steel may be used safely, in relation to notch brittleness. Experimental work is described on effects of variation in notch dimensions on impact value at subzero temperatures. Further work determines effect on impact values of the surface cold-working resulting from grinding and machining, and indicates beneficial effect of stress-relieving in removing harmful effects of cold work on the surface. Practical experiments on small welded vessels in mild steel are then described, the vessels being tested to destruction at −80 C. This work indicates that, while such vessels ultimately fail in a brittle manner, actual rupture is preceded by a considerable amount of plastic flow. It is argued, from these results, that the

observed plastic flow gives adequate assurance that properly constructed mild-steel welded vessels can absorb local overstressing to an appreciable extent without rupture, and this conclusion is supported by stress-strain diagrams taken at subzero temperatures.

Results of the investigation are the basis for conclusion that, provided recommended precautions as to quality of material and care in fabrication are taken, mild-steel welded equipment may safely be used at subzero temperatures down to —50 C.

From authors' summary

2959. **Neighbours, J. R., and Smith, C. S., An approximation method for the determination of the elastic constants of cubic single crystals,** *J. appl. Phys.* **21,** 12, 1338–1339, Dec. 1950.

The possible 21 constants relating stress to strain in the classical theory can be simplified to three elastic constants for crystals having cubic symmetry. These three elastic constants may be determined from measurements of the three wave velocities in an arbitrary direction in the crystal. The mathematics of an approximate method of doing this by making use of the perturbation method is given.

In the 110 direction in the cubic crystal, all three elastic constants can be determined from the wave velocities, and in this direction the perturbation terms are zero. The three elastic constants cannot be determined from velocity measurements in the 100 or 111 directions. In other directions all three constants may be determined; the size of the perturbation corrections will depend upon the specific directions chosen.

This method of determining elastic constants has the advantage that crystals need not be cut in special orientations for measurements of wave velocities in special simple directions.

Lawrence Nielsen, USA

2960. **Sundara Rao, R. V. G., Elastic constants of orthorhombic sulphur,** *Proc. Indian Acad. Sci. Sec. A.* **32,** 4, 275–278, Oct. 1950.

The elastic constants of single crystals of orthorhombic sulphur have been determined by the ultrasonic method.

From author's summary

2961. **Jona, F., Elasticity of piezoelectric and seignette-electric crystals** (in German), *Helv. phys. Acta* **23,** 6/7, 795–844, Dec. 1950.

Author shows that Schaefer-Bergmann method (diffraction of light by crystal vibrating in high mode) measures elastic constants c_{ik} at constant zero electric field, not at constant dielectric displacement. This is because piezoelectric charges on surface form a periodic pattern, field of which decays exponentially from surface. Constants of Rochelle salt (except c_{44}) are linear functions of temperature, with no anomaly at Curie points, contrary to results of Mason. High damping of corresponding wave made c_{44} unmeasurable. Measurements also on $NaClO_3$, KD_2PO_4, RbH_2PO_4. Theoretical explanation is given of absence of certain predicted diffractions, enhancement of others.

F. R. N. Nabarro, England

2962. **Payne, R. J. M., Stress relief and allied problems in magnesium alloy castings,** *J. Inst. Metals* **78,** part 2, 147–168, 1950.

Describes method of assessing stress-relief anneals for magnesium-alloy castings and recommends heat treatments for AZ 91, A 8, Elektron Z5Z, and Elektron MCZ alloys.

Wedges are inserted into stress-free split-ring castings which are then annealed. After cooling, wedges are removed and amount of springback is measured as indication of residual stress. Author found that time and temperature are inversely related in a manner similar to that for recrystallization. For annealing times of 144 hr, stress relief proceeds to a level dependent upon the temperature.

For AZ 91 and A 8, annealing at 330 C for 2 hr achieves relief of 95% of stresses and does not appreciably affect mechanical properties of sand-cast alloys.

For Z5Z, 2 hr at 330 C not only provides stress relief but also develops optimum mechanical properties and permits simultaneous straightening of warped castings. Author notes that it has been subsequently found that an additional 24 hr at 180 C results in further improvement in mechanical properties.

For MCZ creep-resistant alloy, minimum temperatures suitable for stress-relief also cause loss of creep strength, presumably as a result of overaging. Stress relief combined with solution heat treatment at 570 C, followed by an air-cool rather than a quench (which might introduce new residual stresses) seems to offer best treatment for castings later to be used at operating temperatures of 200 C.

Carl A. Keyser, USA

2963. **Werren, F., Effect of prestressing in tension or compression on the mechanical properties of two glass-fabric-base, plastic laminates,** *For. Prod. Lab. Rep.* 1811, 12 pp., Sept. 1950.

Report presents results of 36 tension and 45 compression tests made on two glass-fabric-base plastic laminates. Laminated specimens were prestressed to various percentages of ultimate stress, and a study was made of effect of this prestressing on mechanical properties and set. All tests were made after normal conditioning of specimens. Tests showed that with 181-114 laminate, resin 2, stress-strain curve of material after it had been prestressed in tension was different from stress-strain curve obtained on first application of stress. Thus, for laminates of this type, results indicate that values of modulus of elasticity and of proportional limit, as calculated from usual tensile stress-strain curve, may be considerably in error once material has been stressed beyond initial proportional limit. 143-114 laminate, resin 2, showed same type of stress-strain curve whether or not prestressed. Tensile strength of neither type appears to be affected by prestressing.

Compressive properties of the two laminates were not appreciably affected by prestressing. The greater the degree of prestressing in tension or compression, the greater was observed set. However, set is of small absolute magnitude.

From author's summary

2964. **Homès, G. A., and Gouzou, J., Contribution to the study of the mechanism of failure of metals** (in French), *Rev. Métall.* **47,** 9, 678–692, Sept. 1950.

Authors have made a preliminary series of experimental tests to contribute to the knowledge and prevention of metallic failures. With an excellent technique and using an interesting testing machine, they study specimens of zinc, copper, iron, carbon steel, etc. They give results for pure and commercial zinc at room temperature, for pure zinc at high temperature, and first results for steel. They note that even in the simple case of failure by traction, there are different mechanisms of failure, i.e., (a) pure cleavage, (b) cleavage accompanied by separation, (c) sliding followed by separation. Cases (a) and (b) appear in zinc at room temperature. Case (c) happens generally with steel and zinc at high temperatures. In zinc, as well as in steel, they have observed important heterogeneity during the deformation and failure. In zinc, the three ways of failure vary from a grain to another. In steel, it can be attributed to the effect of a momentary hoop, caused by cementite surrounding the ferrite grains.

Reviewer believes paper adds useful information and shows that

good results can be expected with technique used. The large number of photographs are clear and illustrative.

F. G. Olano, Argentina

2965. **Wetenkamp, H. R., Sidebottom, O. M., and Schrader, H. J., The effect of brake shoe action on thermal cracking and on failure of wrought steel railway car wheels,** *Univ. Ill. Engng. Exp. Sta. Bull.* **47,** 77, 101 pp., June 1950. $0.60.

Two types of tests were performed: (1) Wheels were stopped from high speed by using high brake-shoe pressure, and (2) wheels were tested under long-continued applications of the brake shoes. The stop tests were intended to produce thermal cracks in the wheel treads. The long-continued brake-shoe applications were intended to produce fractures through the rims and plates of the wheels. In both types of tests the conditions imposed on the wheels were more severe than the wheels should receive in normal railway operation.

Studies of the effect of carbon content of the wheel material, various methods of heat treatment, and changes in wheel design, together with a qualitative analysis of the stresses developed in the wheels are presented.

The results apply only to the types of wheels tested. These do not necessarily represent all wheels made by the various manufacturers. The types of failures, however, are in close accord with experience in service. From authors' summary

2966. **Kochendörfer, A., On the strength properties of metals at low temperatures** (in German), *Z. Metallk.* **41,** 10, 322–325, Oct. 1950.

Author refers specifically to tests by K. Wellinger and W. Seufert [see following review] on the effect of low temperature (-180 C) on the yield strengths and the strain-hardening rates of both face-centered cubic and body-centered cubic multicrystalline metals. He shows that the two different behaviors found are explained quantitatively by published theories [Kochendörfer, A., "Plastische Eigenschaften v. Krisatllen u. metallischen Werkstoffen," Springer, 1941; title source, **38, 39;** 173, 376].

M. P. White, USA

2967. **Wellinger, K., and Seufert, W., Investigations on strength behavior of metallic materials at low temperatures** (in German), *Z. Metallk.* **41,** 10, 317–321, Oct. 1950.

Uniaxial compression tests at low (-180 C) and at room temperatures were made on several metals, yielding stress-strain curves. Two distinct kinds of behavior were observed. (1) Soft iron (0.08 C) and plain carbon steel (0.25 C) showed a yield stress at the low temperature approximately three times that at room temperature. The stress-strain curves at the two temperatures were essentially parallel, indicating there is no change in the rate of strain-hardening with temperature. Magnesium behaved similarly. Authors ascribe this behavior to the form of the lattice (body-centered cubic and hexagonal, respectively). (2) Aluminum, lead, copper, and austenitic steel (face-centered cubic lattice) show no or very little difference in yield stress between room and low temperatures. The rate of strain-hardening is much greater at low temperatures. [See preceding review.]

M. P. White, USA

2968. **Spretnak, J. W., and Wells, C., An engineering analysis of the problem of quench cracking in steel,** *Trans. Amer. Soc. Metals* **42,** 233–266, 1950.

Results of study of quench-cracking data obtained in commercial practice reveal considerable information regarding quench cracking in hollow cylinders. Although cracks occurred on outside surfaces and through walls, preponderance of cracks were bore surface type. Authors suggest that peak temperature during quench occurs nearer bore such that stresses associated with austenite transformation will be more severe at bore.

Statistical nature of quench cracking is emphasized. Frequency of cracking with many variables is studied. Frequency increased with decreased ingot pouring temperature, decreased forging reduction, increased ingot size, and proximity to bottom third of ingot. Carbon content was significant factor showing frequency increase with increased carbon content. Frequency also increased with decreased temperature at end of quenching. Total alloying elements and end-quench hardenability showed low correlations with cracking. Uniformity of quench was an important factor.

Quench cracking could be reduced by interrupted quench and by a prebore quench, whereby the bore is first quenched in a prescribed manner prior to complete immersion of the specimen in the quenching bath. Louis F. Coffin, Jr., USA

Mechanics of Forming and Cutting

(See also Rev. 2922)

2969. **Ruddle, R. W., and Skinner, R. A., Heat extraction at corners and curved surfaces in sand moulds,** *J. Inst. Metals* 79, part 1, 35–56, 1951.

Rate at which a sand mold removes heat from corners (both external and re-entrant) and curved surfaces of castings has been determined by means of temperature measurements made in the mold. Heat is extracted considerably more rapidly from a convex surface or an external corner of a casting than from a plane surface; the difference is decreased by increasing the radius of the surface or by radiusing the corner. Rate of heat extraction at a re-entrant corner is slightly less than that from a plane surface. The solidification times of castings can be roughly calculated using a mathematical analysis of the heat flow through a plane surface, and more accurate estimates are possible by using the correction factors given in this paper for corner and curvature effects. From authors' summary

2970. **Fusfeld, H. I., and Feder, J. C., Study of deformation at high strain rates using high-speed motion pictures,** *Amer. Soc. Test. Mat. Bull.* no. 170, 75–79, Dec. 1950.

Report describes a method for studying the geometry of deformation processes at drawing speeds using high-speed motion pictures. A shadow technique is used which permits measurements of strain and of shape of the neck throughout a tension test at high speeds.

Method has been applied to obtain curves of the sharpness of neck vs. strain, data similar to that used by P. W. Bridgman to correct stress-strain curves for true tensile stress once necking has set in. Results of preliminary tests show that: (1) Comparison of results for steel, aluminum, and brass with results obtained by Bridgman in "static" tension tests shows that the true uniaxial tensile stress during tests at speeds used (100 in. and 1000 in. per min) is on the order of 5% higher than would be calculated from Bridgman's results. (2) Change in formation of neck as a function of speed of test provides an indication of manner in which strain-hardening varies with strain rate; steel and aluminum showed little change at 100 in. per min, more at 1000 in. per min, while brass showed considerable change at the first speed and little more at the faster speed. (3) Strain at which necking occurs tends to increase with increasing speed of test.

From authors' summary

Hydraulics; Cavitation; Transport

(See also Rev. 3104)

2971. **Al'tshul', A. D., Law of pipe resistance** (in Russian), *Doklady Akad. Nauk SSSR* (*N.S.*), **76**, 6, 809–812, Feb. 1951.

Author develops a universal formula for pipes of various roughnesses:

$$f^{-0.5} = 1.8 \log [Re/(Re\Delta/d + 7)]$$

where f is coefficient of roughness, Re Reynolds number, d pipe diameter, Δ generalized linear unevenness of walls. At small values of Re, formula becomes $f^{-0.5} = 1.8 \log (Re/7)$ and is similar to the Colebrook-White formula for smooth pipes. At large values of Re, it approaches the Nikuradse formula for rough pipes. This equation gives a straight line on semilogarithmic paper and shows, in the limits of Re from 3.10^3 to 20.10^6, a reasonable agreement with the experiments by Davis, Saph and Schoder, Freeman, Hickox, Nikuradse, and by several Russian experimenters. Author recommends values of the linear unevenness Δ: smooth pipes 0, plywood 1 to 2, seamless steel 0.6 to 2, steel pipes 3 to 10, asphalted cast iron 10 to 25, galvanized iron 12 to 30, cast iron 25 to 50, concrete 20 to 100. These large limits undermine the precision of the new formula.

Steponas Kolupaila, USA

2972. **Teofilato, S., Preliminary study of transitions between channels with lined and unlined beds** (in Italian), *Energia elett.* 27, 8, 461–470, Aug. 1950.

Laboratory experiments are made to determine the bottom erosion at the transition between channels with lined and unlined beds. Two sets of experiments are made, one with a rectangular cross section of widths varying from 0.4 to 1.20 m, and the other with trapezoidal cross sections. The amount of erosion is tabulated for various flows for both series of experiments and, in the second series, several transition structures designed to reduce the bed erosion are investigated. Vito A. Vanoni, USA

2973. **Viparelli, M., On a special type of over-flow and on the out-flow with vortex** (in Italian), *Energ. elett.* **27**, 10, 610–624, Oct. 1950.

Results are reported of some experiments made in the Hydraulics Laboratory of the University of Naples on different types of a device for evacuation through a vertical tube, where the depression is avoided by an artificially produced vortex. Shape of the free surface of the vortex was determined for different values of discharge. Results are discussed on the basis of some theoretical considerations, showing in particular that the vortex cannot be of the irrotational type. Formulas and diagrams are given for computing the discharge and for correct design of the device.

Duilo Citrini, Italy

2974. **Escande, L., Effect of removal of the boundary layer on the functioning of large hydraulic structures** (in French), *C. R. Acad. Sci. Paris* **232**, 12, 1182–1183, Mar. 1951.

Twelve laboratory photographs show pronounced improvement in pattern of flow at various hydraulic structures as the result of boundary-layer removal. Hunter Rouse, USA

2975. **Escande, L., Consideration on some modern methods of calculation of the water hammer in penstocks** (in Spanish), *Teen. Metalurg.* **6**, 50, 52; 155–165, 252–258; May, July 1950.

A graphical method, essentially the method of characteristics, is used to determine the pipe stresses occasioned by surges in hydraulic systems. A number of problems are worked out in detail. Lawrence Talbot, USA

2976. **Schweitzer, P. H., and Szebehely, V. G., Gas evolution in liquids and cavitation,** *J. appl. Phys.* **21**, 12, 1218–1224, Dec. 1950.

Eighteen liquids were tested for their air solubility, and for their rates of solution and evolution of air when equilibrium with the surrounding air in the container was disturbed. Although solubility constants, and solution and evolution rates differed for the various liquids under similar tests conditions, it was found that: (1) Rate of evolution (solution) is proportional to supersaturation (undersaturation); and (2) evolution process is quicker than solution process. Cavitation and the role of entrained air in cavitation are discussed.

Morris S. Macovsky, USA

2977. **Acevedo, M. L., Cavitation on marine propellers and its prediction based on the results of tests with profiles,** *David W. Taylor Mod. Basin Transl.* 230, 47 pp., Jan. 1951.

See AMR **3**, Rev. 923.

2978. **Einstein, H. A., The bed-load function for sediment transportation in open channel flows,** *U. S. Dept. Agric. Soil Conserv. Serv. tech. Bull.* 1026, 71 pp., Sept. 1950.

Author divides the total sediment transport into (a) wash load consisting of those particles which are finer than the material of the stream bed, and (b) bed-material load consisting of grain sizes included in the bed. Paper develops by analytical, statistical, and empirical methods a bed-load function which gives the rate of transport of the bed-material load. This function is given in terms of measurable stream parameters. Use of function is illustrated by field example treated in clear systematic fashion. Necessary charts are included with bulletin. Author's treatment includes discussion of limitations as well as advantages of method and suggests further improvements and investigations. Reviewer emphasizes that while bed-load function does not give information on wash load, it gives rate of transfer of bed-material load both in suspension and as a bed-load, i.e., as rolling and sliding load along the bed surface. Dwight F. Gunder, USA

2979. **Epstein, P. S., and Plesset, M. S., On the stability of gas bubbles in liquid-gas solutions,** *J. chem. Phys.* **18**, 11, 1505–1509, Nov. 1950.

Diffusion equations are obtained and solved approximately for the dissolving or growth of a spherical gas bubble surrounded by a liquid-gas solution. Effect of surface tension is considered. Effects of the motion of the gas bubble as a whole are neglected.

A. Schild, USA

2980. **Laboratoire Dauphinois d'Hydraulique, Flowmeter for rapidly varying flow** (in French and English), *Houille blanche* 5, 5, 574–577, Sept.-Oct. 1950.

Device consists essentially of a propeller comprising two blades of 45° pitch; at one end of the supporting axle, a brass wheel with 24 teeth is mounted. Two insulated brass electrodes are fixed to the main frame on blocks of impregnated wood; they are placed at opposite ends of a diameter of the wheel from which they are separated by a few tenths of a millimeter. The rotation of the current meter causes periodic variations in the resistance between the electrodes; these variations are then recorded on a cathode-ray oscillograph, the signals being transcribed on photographic paper. In this way, it is possible to measure not only the speed of rotation of the propeller, but also speed variations over a fraction of a revolution. From summary

2981. Lombardi, J., and Marquenet, G., The rational design of a stepped channel consisting of a series of loose-bed stilling pools for regularizing a torrential stream (in French), *Houille blanche* **5**, no. B, 730–746, Nov. 1950.

Article deals with an investigation both by theory and by model tests to study the best channel design for regularizing a torrential river. The purposes are: (1) To prevent changes in the stream bed by means of vertical training walls; (2) to dissipate the energy of the stream by successive hydraulic jumps; (3) to insure that the slope of the channel is sufficient for bed-load transportation. Charts have been constructed which permit a perfectly general solution applicable to any torrential river. The method can be extended to streams where slope and width are variable.

André Leclerc, Canada

2982. Leclerc, A., Deviation of a liquid jet by means of a plate normal to the axis of the former. Determination of the free surface by electrical analogy (in French), *Houille blanche* **5**, 6, 816–821, Nov.-Dec. 1950.

The three-dimensional electrical analogy of a perfect liquid in irrotational motion, when neglect is made of gravity, is well known [see Ferrari, *Aerotecnica*, no. 6, 1930]. It is used here for establishing free surface, velocity, stream, and equipotential lines of a liquid jet normal to an infinite plate. Results confirm measurements made in 1901 by W. M. White using a Pitot tube [see *J. Assn. Engr. Soc.*, 1901]. Author's results explain also (by cavitation) some erosions found in Beton surfaces struck by water jets.

Giulio Supino, Italy

2983. Chang, H.-L., Simple methods for the determination of equivalent pipes and flow distribution in parallel pipe systems, *Sci. Rec. Shanghai*, **2**, 4, 408–416, Nov. 1949.

Author presents a chart giving a direct solution to flow of water through a complicated piping network having one point of supply and one point of consumption. The chart is based on the Hazen-Williams formula, but method could be used with any empirical formula which can be reduced to the form: $h = K^n Q^n$ in which h is the head loss through the system, K is a constant depending on the system dimensions, and Q is the volume rate of flow. Within the accuracy of the formula, the method gives strictly accurate results. A direct answer is obtained without cut and try if only one supply and point of use is involved.

Method cannot be used with the more recent rational correlations of flow test data such as summarized by Lewis F. Moody in "Friction factors for pipe flow," *Trans. Amer. Soc. mech. Engrs.* **66**, 671–678, Nov. 1944. Theodore E. Bridge, USA

2984. Lu, H., Phenomenological theories of bulk viscosity, *Chin. J. Phys.* **7**, 5, 365–375, Sept. 1950.

Sound attenuation in polyatomic gases and liquids is due partially to relaxational phenomena which are not considered in the Stokes equations. In the case of gases, a much larger number of collisions is required for the molecular rotation and vibration to attain equilibrium state than for the translation. The resulting time lag, if not small compared to the period of the sound wave, results in dissipation of energy. In liquids a uniform dilatational movement of the molecules causes a variation of their structure, which lags behind the uniform motion.

Author divides the relative compression $s = -\Delta V/V$ into two parts, an instantaneous and a relaxational part. Latter is due to viscous character of the liquid or gas-like material. He assumes, as did Maxwell, the variation of the relaxational part with time to be proportional to the excess of mean dynamic pressure $\bar{p}$ over effective pressure p, $(ds/dt)_{rel.} = (\bar{p} - p)/\eta_2$. With the reciprocal of the proportional coefficient he brings in a second constant of viscosity called the bulk or volume viscosity. With the assumption that the excess of stress over the effective dynamic pressure is proportional to the rate of strain due to viscous flow, he attains an enlarged Stokes equation:

$$\rho \frac{d\vec{v}}{dt} = \rho\vec{f} - \nabla p + (\tfrac{1}{3}\eta_1 + \eta_2)\,\nabla\nabla\cdot\vec{v} + \eta_1\nabla^2\vec{v} + \eta_2\beta_\infty\nabla(dp/dt);$$

β_∞ = instantaneous part of compressibility. Proceeding from this equation, author calculates the attenuation of a plane sound wave. Ulrich Rost, Germany

2985. Morris, W. J., and Schnurmann, R., Temporary reduction of viscosity of liquids at high rates of shear, *Nature* 167, 4243, p. 317. Feb. 1951.

The viscosity of tetradecane was measured at 6.5 to 35.3 C in a jet viscometer. At shear rates of about 300,000 reciprocal sec, the viscosity reached a minimum some 25% below that at zero rate. Evidently any liquid will show decreased viscosity at high enough shear rates. C. F. Bonilla, USA

2986. Viguier, G., Analytical structure of the new mechanics of viscous fluids (in French), *Revue Sci.* **87**, 86–88, 1949.

Author makes a formal extension of the theory of viscous fluids by assuming that the viscous stresses depend on velocity derivatives in a nonlinear manner, including terms of the third order.

C. C. Lin, USA

2987. Müller, W., Friction losses in the high-pressure pipe line and distributing system of the Lucendro power station, Switzerland, *Sulzer tech. Rev.*, no. 4, 1–11, 1949.

Incompressible Flow: Laminar; Viscous

(See also Revs. 2804, 2920, 2983, 3056, 3080)

2988. Dolaptchiev, B., Stabilization of vortex streets (in French), *C. R. Acad. Bulgare Sci. Math. Nat.* **2**, 2–3, 13–16, 1949.

Author considers two infinite parallel rows of equally spaced point vortexes, calling the general configuration of this type "asymmetric" to distinguish it from the well-known symmetric and alternating vortex streets. The asymmetric configuration, which is known to be in equilibrium, has been shown by Godefroy [*Comment. math. helvet.* **11**, 298–320, 1939], Maue [*Z. angew. Math. Mech.* **20**, 129–137, 1940], and author, to be stable (with respect to a certain wide class of small perturbations), provided the configuration satisfies the relation (*) $\sinh h\pi/l = \sin d\pi/l$, where h is distance between the rows, l spacing of the vortexes in each row, and d distance along the axis that each row is displaced from the symmetrical configuration. Author shows that if a stable Kármán vortex street is perturbed through a sequence of asymmetric configurations, the velocity of system being that of the instantaneous asymmetric configuration, then the motion of the vortexes is such that (*) is satisfied at each instant. Author uses this result as basis for a qualitative explanation of why the Kármán street is the only stable configuration observed in nature.

Courtesy of Mathematical Reviews D. Gilbarg, USA

2989. Truesdell, C., Vorticity averages, *Canad. J. Math.* **3**, 1, 69–86, Jan. 1951.

Transfer of vorticity and rotational flow are important for an engineer, particularly when one attacks flow in boundary layer or behind a shock. Paper represents a nice contribution to a deeper understanding of the phenomenon of transfer of vorticity.

In the first part, author cites known vorticity theorems in plane flows, i.e., Poincaré's integrals of "vorticity mass," "center of vorticity mass," "moment of inertia," and integral of Hamel. Part closes with comparison of those integrals and clarification by Synge that Hamel's theorem is a special case of a characterization of plane fields defined within and vanishing upon a single closed boundary. In the second part, author discusses known vorticity integrals for three-dimensional motion, i.e., those of Lamb, Poincaré, Berker for isochoric motion (i.e., divergence of velocity vanishes identically) and of Moreau for isochoric circulation-preserving motions. The validity of those integrals is limited and some integrals for wider classes of motions may be found by Kelvin's transformation. Föppl's three-dimensional generalization of Poincaré's mass and integrals of Jaffe are also mentioned. In the last part, author introduces his idea of symmetrical moments of vorticity by means of polyadic nth powers of a vector and shows that previous theorems and integrals are the simplest special cases of his two general conservation theorems. The way of doing it is instructive and proves that, in mathematics, generalization often brings simplification. Reader should be well acquainted with vector and Gibbs' tensor notation.

M. Z. Krzywoblocki, USA

2990. **Muskat, M., The effect of permeability stratification in complete water-drive systems,** *J. Petr. Technol.* **2**, 12, 349–358, Dec. 1950.

A theory is presented for calculating the performance history of complete water-drive systems producing from idealized stratified formations. The general equations are applied to systems where the permeability stratification is either of exponential or linear type. Calculations were carried through for different degrees of permeability stratification, but with special emphasis on the effect of the mobility ratio between the produced oil and the invading water on the resultant performance. These results are also expressed graphically as curves for the initial water breakthrough recovery, for the different degrees of stratification, as a function of the mobility ratio, and of the composition of the produced fluid stream as a function of the cumulative oil recovery. For several typical cases the latter has also been plotted as a function of the cumulative oil and water throughflow. The general result is that, when the mobility of the oil is lower than that of the invading water, the channelling tendency resulting from the permeability stratification becomes aggravated as the higher permeability zones become flooded out. Situations of this type would obtain when producing low gravity or highly viscous oils. Conversely, if the mobility of the oil is high compared to that of the invading water, the flooding of the high permeability zones will lead to a retarding and choking effect, and the gross bypassing phenomena will be partially suppressed. These conditions would correspond to those of flooding high gravity or low viscosity oils. A discussion is given of the various basic assumptions made in the analysis, including that of ignoring the stripping phase of the production history as implied by relative permeability concepts.

From author's summary by R. E. Fadum, USA

2991. **Preston, J. H., Non-steady flows under asymptotic suction conditions,** *Quart. J. Mech. appl. Math.* **3**, part, **4** 435–445, Dec. 1950.

As another phase of a previous paper [AMR **4**, Rev. 753], the transient problem of the incompressible viscous flow about a rotating circular cylinder under uniform surface suction is investigated under the condition that the angular cylinder speed and/or the suction velocity is suddenly changed. The corresponding transient solution can be obtained approximately in a closed form if the suction or the Reynolds number $R = w_0 a/\nu$ is sufficiently large (w_0 is normal suction velocity, a radius). It is found that the velocity distribution lies between those of the initial and final steady-state solutions and that the circulation at infinity is unchanged. Author predicts that the above results will be true for smaller suctions, provided that $R(= w_0 a/\nu) > 2$. This analysis gives some verification of Thwaite's statement on his flap that the lift or the total circulation of the wing-flap combination will depend only on the forward speed and will scarcely be affected by gusts. This asymptotic solution of the cylinder for large R is applicable to the infinite flat plate for all suction velocities ($R \to \infty$) and is exact in this case. The effective transient duration is short and is inversely proportional to the square of the suction velocity.

Chieh-Chien Chang, USA

2992. **Iversen, H. W., and Balent, R., A correlating modulus for fluid resistance in accelerated motion,** *J. appl. Phys.* **22**, 3, 324–328, Mar. 1951.

Paper presents results of an experimental study of the drag on a disk in unidirectional accelerated motion in a direction normal to its surface due to the virtual mass of the fluid. The drag coefficient, expressed in the usual manner, is plotted as a function of a correlation modulus for accelerated flow which is defined as the product of a characteristic length of the body times the acceleration divided by the square of the velocity. For large values of the correlation modulus, test results show good agreement between the measured value of the Bessel added mass constant, k, and the theoretical value as calculated by potential theory. For low values of the correlation modulus, k reaches a value approximately five times the theoretical value. Data presented appear remarkably consistent considering that all parameters were evaluated by graphical differentiation of space-time curves. The test procedure tended purposely to minimize the effects of Reynolds modulus and Froude modulus on the test results. As is noted by authors, the present test results do little more than establish the drag coefficients of a disk moving in a direction normal to its surface as a function of this correlation modulus for fluid resistance in accelerated motion. Further work is planned to study objects other than disks.

J. E. Stevens, USA

2993. **Betz, A., Flow phenomena in revolving blade channels** (in German), *Termotecnica* **5**, 1, 25–28, Jan. 1951.

Flow in channel formed between two radial blades rotating at speed $+\omega$ is investigated by referring motion to a system of axes connected therewith. Configuration of field is arrived at by separately determining: (a) Flow at constant rotation $-\omega$, which meets requirements of zero normal velocity at walls and zero flow inside channel; (b) potential flow having zero normal velocity at walls and a discharge inside the channel determined by a given velocity; and by then superposing both fields.

It is shown that, in contact with one of the walls, there will be a point A, having zero velocity, from which a streamline starts, originating a flow similar to that corresponding to separation in a boundary layer. Equation of dividing line is deduced, and angle formed by the latter with the wall at A is determined.

From author's summary by H. Thygesen Kristensen, Sweden

2994. **Lu, Hsih-Chia, On the surface of discontinuity between two flows perpendicular to each other,** *Engng. Reps. nat. Tsing Hua Univ.* **4**, 1, 40–62, Oct. 1948.

Author investigates problem of circular jet entering perpendicularly into uniform flow. Assumption is made that jet velocity is comparatively large so that deformation occurs in planes perpendicular to jet direction. It is further assumed that any material cross section of jet deforms in time in same way as an

initially circular body of dead water placed in appropriate two-dimensional flow. (Reviewer feels this assumption unjustified and probably incorrect.) Potentials of outer and inner flow are expressed in power series with time-dependent coefficients; boundary equivalence of pressures and normal displacements allows comparison of coefficients. Cross section is found to become kidney-shaped. Same result is obtained by replacing cylinder surface by vortex sheet. Author claims unpublished experimental values agree. Carl E. Pearson, USA

2995. **Zilsel, P. R., Liquid helium II. The hydrodynamics of the two-fluid model,** *Phys. Rev.* (2) **79,** 309–313, 1950.

Nonlinear equations of motion for reversible processes in the two-fluid model of liquid helium II are derived from a variation principle of a type first introduced by Eckart [title source (2) **54,** 920–923, 1938]. Possibility of transitions between the two fluids, disregarded so far, has been taken into account. Theory leads to a new equilibrium condition between the two fluids depending on their relative velocity.

Courtesy of Mathematical Reviews F. London, USA

Compressible Flow, Gas Dynamics

(See also Revs. 2821, 2823, 2867, 2979, 3026, 3035, 3043)

2996. **Mack, C. E., Jr., and Kolodner, I. I., Linearized treatment of supersonic flow through axisymmetric ducts with prescribed wall contours,** New York, Inst. aero. Sci., S.M.F. fund paper 286, 1950, 63 pp. $1.25.

This is an application of the linear small perturbation theory of supersonic flow to problems of the internal steady axisymmetric flow through a duct of nearly constant cross section. First, a numerical method of solution is given, based on determining a distribution of source rings on a circular cylinder through the lip of the duct, such as will cause the boundary condition at the surface to be satisfied. There is a considerable discussion of the fact that if the duct becomes parallel the flow continues to oscillate without damping. Secondly, a discussion of the problem based on the Laplace transformation is given, in which solutions in the form of Fourier-Bessel expansions are approximated by replacing the functions of the Fourier-Bessel system by their asymptotic forms. This approximate solution shows up the nature of the oscillations clearly. In this second part the authors seem to follow G. N. Ward [AMR **1,** Rev. 1509] very closely.

M. J. Lighthill, England

2997. **Czarnecki, K. R., and Mueller, J. N., An approximate method of calculating pressures in the tip region of a rectangular wing of circular-arc section at supersonic speeds,** *Nat. adv. Comm. Aero. tech. Note* 2211, 24 pp., Oct. 1950.

A method is presented which consists essentially in applying wing-tip corrections to the two-dimensional airfoil pressure field. Corrections are applied to both pressure increments due to airfoil angle of attack and thickness and require a separate determination of both effects, since the basic two-dimensional field is computed by using either the method of characteristics or the oblique-shock and Prandtl-Meyer expansion techniques. The corrections proceed on Busemann's conical-fields method (flat plate at required angle of attack) and on Jones' method of semi-infinite line sources and sinks (airfoil of prescribed thickness and shape at zero angle of attack), the pressure disturbances from the tip leading edges being assumed in this case to propagate along curved Mach lines. A better approximation to actual flow conditions than is possible with the three-dimensional linearized theory is performed and accuracy of the method is attested by some experimental results of a 9% thick airfoil at different angles of attack and a Mach number $M_0 = 1.62$.

The exactness of proposed corrections depends directly upon the accuracy attainable in determining the basic two-dimensional pressure field. The whole procedure results in somewhat laborious calculations and affects unfortunately the indisputable practical importance of the method. P. Schwaar, Switzerland

2998. **Lomax, H., Heaslet, M. A., and Fuller, F. B., Formulas for source, doublet, and vortex distributions in supersonic wing theory,** *Nat. adv. Comm. Aero. tech. Note* 2252, 35 pp., Dec. 1950.

Formulas of supersonic wing theory for source, doublet, and vortex distributions are reviewed and a systematic presentation relates these distributions to the pressure and to the vertical induced velocity in the plane of the wing. It is shown that care must be used in treating the singularities involved in the analysis and that the order of integration is not always reversible. Further, it is shown that the use of the complex variable can often facilitate the calculation of the integrals involved.

From authors' summary by John V. Becker, USA

2999. **Martin, J. C., Retarded potentials of supersonic flow,** *Quart. appl. Math.* **8,** 4, 358–364, Jan. 1951.

Linearized unsteady supersonic flow is considered and the idea of hyperbolic vector operators due to Robinson [*Quart. J. Mech. appl. Math.* **I,** 408–433, 1948] is adapted to determine the potential at a point in terms of conditions on the disturbing surfaces. Formulas analogous to the Kirchhoff formula are derived; these are interesting but no application is given. Paper is summary of thesis and is too condensed for the analysis to be readily followed.

A. D. Young, England

3000. **Lagerstrom, P. A., and Graham, M. E., Remarks on low-aspect-ratio configurations in supersonic flow,** *J. aero. Sci.* **18,** 2, 91–96–100, Feb. 1951.

Slender-body theory provides solutions for low-aspect-ratio wing-body combinations which indicate that the lift is independent of afterbody length. Purpose of this paper is to obtain a greater understanding of wing-body interference by examining the aerodynamic characteristics of carefully selected low-aspect-ratio configurations (both planar and nonplanar) for which solutions can be found not only by slender-body theory but also by the more exact linearized three-dimensional theory. Authors conclude that, for no afterbody, slender-body theory overestimates the lift, but that for a short afterbody it may equal or even underestimate the lift. For an infinitely long afterbody it agrees exactly with linear theory if the afterbody diameter equals the maximum wing span; if the afterbody is narrower, it overestimates the lift. John R. Spreiter, USA

3001. **Coburn, N., Compressible supersonic flow in jets under the Kármán-Tsien pressure-volume relation,** *J. appl. Phys.* **22,** 2, 124–130, Feb. 1951.

Mathematical paper gives relations between physical, hodograph and (velocity potential, stream function) planes which apply to a two-dimensional supersonic gas jet, using the Kármán-Tsien approximation to the adiabatic. The map of the flow in the hodograph plane possesses a folding property which is connected with the periodic character of the jet boundary. Reviewer notes that the velocity components, when expressed as partial derivatives of the stream function, require the opposite signs to those given in the paper, if the initial conditions are to be satisfied. The argument is unaffected. D. C. Pack, Scotland

3002. **Travers, S., The present state and value of the hydro-thermodynamic theory of explosions and shocks** (in French), *Mémor. Artill. fr.* **24**, 3, 487–553, 1950.

An elementary review of the properties of shocks in gases, liquids, and solids. For the two latter media the Tammann equation of state $(p + p_i)(v - \alpha) = f(T)$ is used, where $f(T)$ fits thermal expansion data. H. H. M. Pike, England

3003. **Miles, J. W., On nonsteady motion of slender bodies,** *Aero. Quart.* **2**, part 3, 183–194, Nov. 1950.

For slender bodies at an angle of attack, the cross flow in a cross section perpendicular to the free-stream direction can be given by the two-dimensional Laplace equation. The influence of other cross sections is small of higher order. Author shows that same is correct for unsteady flows, and gives some examples.
G. Guderley, USA

3004. **Miles, J. W., Quasi-stationary airfoil theory in subsonic compressible flow,** *Quart. appl. Math.* **8**, 4, 351–358, Jan. 1951.

A solution of the integral equation for an oscillating, two-dimensional, thin airfoil in a compressible flow (subsonic and inviscid) is obtained by retaining only first-order terms in frequency. The results are applied to calculating the damping derivative of a tail in rotary motion about a forward center, and it is shown that the damping is considerably less than that calculated on the basis of stationary airfoil theory. A brief investigation of induction effects shows this reduction to be considerably less for a wing of finite aspect ratio.
From author's summary by W. R. Sears, USA

3005. **Gilles, A., Calculation of pressure distributions on certain thin airfoils** (in French), *Rech. aéro.* no. 19, 3–10, Jan.-Feb. 1951.

Author deals with usual linearized supersonic flow about symmetrical, pentagonal airfoil, subsonic initial triangle edges, rectangular rear, Mach cones from side corners not intersecting parallel sides. He presents 5-decimal table of $\cos \psi_0 - F(\omega, \psi_0)$, F the complete elliptic integral of third kind, for calculating correction to triangular airfoil via formulas credited to P. Germain ["Théorie générale des mouvements coniques," *Off. nat. Étud. Rech. Aéro.* no. 34], and computes examples. Such cases—superpositions of finite number of cone fields—have been treated independently ad nauseum in various countries; cf., for bibliography, W. H. Pell [AMR **4**, Rev. 799], S. Goldstein, and G. N. Ward [AMR 4, Rev. 803]. A. Charnes, USA

3006. **Brinich, Paul F., Boundary-layer measurements in 3.84- by 10-inch supersonic channel,** *Nat. adv. Comm. Aero. tech. Note* 2203, 51 pp., Oct. 1950.

Boundary-layer measurements were made in the transonic and supersonic regions of a channel having maximum cross-sectional dimensions 3.84 by 10 in. and designed by potential-flow methods for a uniform Mach number of 2.08 in the test section. At inlet pressures from 37 to 13 in. of mercury absolute, turbulent boundary layers were observed throughout the channel; at an inlet pressure of 5 in., laminar boundary layers were observed near the channel entrance with turbulent layers downstream.

A comparison of the experimental and theoretically computed boundary layers at the high inlet pressures showed good agreement when empirical friction coefficients were evaluated from Reynolds numbers based on the kinematic viscosity of the air at the wall. Despite this agreement between experiment and theory, local differences in rates of boundary-layer growth still existed that are attributed to secondary flows in the boundary layer.

At low inlet pressures, substantial increases were observed in boundary-layer rates of growth with an uneven development of boundary layer along bottom wall of channel.

Experimental and empirical skin-friction coefficients were in poor agreement at all inlet pressures. Secondary flows in boundary layer caused by static-pressure gradients transverse to stream direction are believed to be the reasons for poor agreement.
From author's summary

3007. **Turner, M. J., and Rabinowitz, S., Aerodynamic coefficients for an oscillating airfoil with hinged flap, with tables for a Mach number of 0.7,** *Nat. adv. Comm. Aero. tech. Note* 2213, 46 pp., Oct. 1950.

Calculations by Dietze are extended to include 4 values of ratio of flap chord to total chord (0.15, 0.24, 0.33, 0.42) and 12 values of the reduced frequency covering the range of 0 to 0.7. Tables of the aerodynamic coefficients for lift, pitching moment, and flap hinge moment are presented. Keith C. Harder, USA

Turbulence, Boundary Layer, etc.

(See also Rev. 3006)

3008. **Stalder, J. R., and Slack, E. G., The use of a luminescent lacquer for the visual indication of boundary-layer transition,** *Nat. adv. Comm. Aero. tech. Note* 2263, 7 pp., Jan. 1951.

Models are coated by a solution of ethocel, a phosphor mixture, and solvents. Dry coating is fluorescent yellow when irradiated by ultraviolet light. Differences in drying rate in laminar and turbulent areas establish patterns. May be observed visually or photographed without undue haste. Luminescent lacquer method appears to be equally as simple and effective as other materials reported previously by others. C. R. Freberg, USA

3009. **Timman, R., A calculation method for three-dimensional laminar boundary layers, Part I. General theory,** *Nat. LuchtLab. Amsterdam Rap.* F.66, 24 pp., 1951.

This treatment of three-dimensional case, analogous to approximate method for two-dimensional case, uses momentum equation. Velocity distribution is assumed to depend on thickness parameter and on parameter dependent on angle between boundary-layer velocity vector and free-stream direction. Set of quasi-linear first-order partial differential equations is obtained, which can be solved numerically by method of characteristics. Discussion of singularity at stagnation point.
Hugh L. Dryden, USA

3010. **Gandin, L. S., On the convergence of the method of Shvets** (in Russian), *Prikl. Mat. Mekh.* **14**, 441–443, 1950.

The polynomial approximation for the boundary-layer velocity profile was developed by Shvets [AMR **3**, Rev. 1544] by application of a method of iteration. By organizing in the same manner a rigorous solution of the problem, convergence of the iterative process is established. N. A. Hall, USA

3011. **Inoue, E., On the smallest turbulon in a turbulent fluid** (in Japanese), *Rep. Inst. Sci. Technol. Tokyo* **4**, 7–8, 195–200, July-Aug. 1950.

The term turbulon is used in this paper as the turbulent element in a fluid which corresponds to Weizsäcker's "Tubulenzelemente." Author intends to make clear the essential differences between the concept of the smallest turbulon in the recent similarity theory of turbulence and that of the smallest eddy in earlier theories.

Making use of the concept of the turbulent viscosity K and putting certain limits of applicability on that concept, author obtains the characteristic scale and velocity of the smallest tur-

bulon as $\Lambda_\infty \sim \nu^{3/4}\epsilon^{-1/4}$, $V_\infty \sim \nu^{1/4}\epsilon^{1/4}$, where ϵ is the turbulent dissipation rate of turbulon energy. For velocity fluctuations with smaller scales than Λ_∞, assuming the mechanism of the laminar dissipation, the negative third-power law of spectrum is obtained which is found in good agreement with Simmons' and Salter's experiments.

The several relationships between Λ_∞ and Taylor's smallest eddies λ_η and λ are shown in terms of K. Using the general characteristics of K in a wind tunnel, relationships between these lengths and the mean wind velocity U are obtained. In particular, the ratio λ_η/λ is shown to be by no means a constant quantity but to change in proportion to $U^{1/4}$.

Some considerations concerning the possibility of direct measurements of the smallest turbulon are discussed with respect to the concept of coherence force of turbulon which is shown to be maximum for the smallest turbulon. From author's summary

3012. Deissler, R. G., Analytical investigation of turbulent flow in smooth tubes with heat transfer with variable fluid properties for Prandtl number of 1, *Nat. adv. Comm. Aero. tech. Note* 2242, 39 pp., Dec. 1950.

Analysis utilizing mixing-length theory with the mutually contradictory assumptions that shear stress and static pressure are constant across the tube is stated without comment. As in author's previous paper [AMR **4**, Rev. 1699], a refinement of the usual theory is computed while retaining the crude approximation of constant shear stress across the tube.

Effect of heat transfer on velocity distribution is computed; heat addition causes flattening, heat extraction peaking, near axis of tube. Analysis indicates the effect of variation of fluid properties with temperature on Nusselt number and friction factor is small if properties are evaluated at average of wall and bulk temperatures. Hugh L. Dryden, USA

3013. Obukhov, A. M., and Yaglom, A. M., The microstructure of turbulent flow (in Russian), *Prikl. Mat. Mekh.* **15**, 1, 3–26, Jan.-Feb. 1951.

In the framework of Kolmogoroff's theory of isotropic turbulence [*Dokladi Akad. Nauk SSSR*, 1941] correlation functions for the velocity, pressure, and acceleration are calculated as functions of a quantity x which is the ratio of the distance between the two points considered and the scale of turbulence η. Here η is introduced from dimensional considerations as $\nu^{3/4}\epsilon^{-1/4}$, where ν is the kinematical viscosity and ϵ the energy dissipation per unit time and per unit mass. Both the cases $x \gg 1$ and $x \ll 1$ are discussed. D. Ter Haar, Scotland

3014. Chandrasekhar, S., The theory of axisymmetric turbulence, *Trans. roy. Soc. Lond. Ser. A*, **242**, 557–577, 1950.

Author develops the theory of axially symmetric tensors and their application in the statistical theory of turbulence by the method used by H. P. Robertson for isotropic turbulence [*Proc. Camb. phil. Soc.* **36**, 209–223, 1940]. Although Batchelor [*Proc. roy. Soc. Lond. Ser. A*, **186**, 480–502, 1946] has also considered this problem, author carries it further to obtain an analog of the von Kármán-Howarth equation of isotropic turbulence.

Let $\boldsymbol{\lambda}$ be the preferred direction, $\boldsymbol{\xi} = \mathbf{r} - \mathbf{r}'$, $(\boldsymbol{\xi}, \boldsymbol{\xi}) = \mathbf{r}^2$, and $(\boldsymbol{\xi}, \boldsymbol{\lambda}) = r\mu$. A solenoidal axisymmetric tensor Q_{ij}, symmetric in the indexes i, j, can be written in the form

$$Q_{ij} = A\xi_i\xi_j + B\delta_{ij} + C\lambda_i\lambda_j + D(\lambda_i\xi_j + \xi_i\lambda_j)$$

where A, B, C, D depend upon two scalar functions of r and μ, Q_1 and Q_2, the "defining scalars" of Q_{ij}. If $Q_{ij} = \overline{u_iu_j'}$, where $\mathbf{u}$ is the velocity at $\mathbf{r}$ and $\mathbf{u}'$ that at $\mathbf{r}'$, then the analog of the von Kármán-Howarth equation is the pair of equations

$$\partial Q_1/\partial t = 2\nu\Delta Q_1 + S_1,$$

$$\partial Q_2/\partial t = 2\nu\Delta Q_2 + 4\nu r^{-2}\partial^2 Q_1/\partial\mu^2 + S_2,$$

where $\Delta = \partial^2/\partial r^2 + 4r^{-1}\partial/\partial r + (1-\mu^2)r^{-2}\partial^2/\partial\mu^2 - 4\mu r^{-2}\partial/\partial\mu$ and S_1, S_2 are the defining scalars for the tensor

$$S_{ij} = \partial(\overline{u_iu_ku_j'} - \overline{u_iu_k'u_j'})/\partial\xi_k + \rho^{-1}(\overline{\partial pu_j'}/\partial\xi_i - \overline{\partial p'u_i}/\partial\xi_j).$$

J. V. Wehausen, USA

Aerodynamics of Flight; Wind Forces

(See also Revs. 2867, 2896, 2897, 2925, 2998, 3000, 3007)

3015. Stough, C. J., and Kauffman, W. M., A flight investigation and analysis of the lateral-oscillation characteristics of an airplane, *Nat. adv. Comm. Aero. tech. Note* 2195, 33 pp., Oct. 1950.

Flight tests were conducted and an analysis made to determine the causes of undesirable dynamic lateral-stability characteristics of an airplane. Various rudder modifications were flight-tested with rudder free and fixed over an indicated airspeed range from approximately 200 to 450 mph. Rudder-hinge-moment and other pertinent data were obtained by flight and wind-tunnel tests.

Oscillation period and time required to damp to one-half amplitude measured in flight are compared with calculated curves in which these characteristics are given as functions of the important rudder-hinge-moment parameters. Analysis of data showed that there were no significant changes in basic rudder-fixed stability derivatives with indicated airspeed, and the rudder-fixed damping characteristics were predictable with sufficient accuracy if the product-of-inertia terms were considered.

Freeing the rudder brought about a reduction in damping of oscillation at low speed; this is attributed to low negative rate of change of rudder-hinge-moment coefficient with rudder deflection and a negative rate of change of rudder-hinge-moment coefficient with angle of sideslip. Further deterioration with indicated airspeed is attributable to effects of Mach number and rudder-tab deflection on these hinge-moment parameters.

From authors' summary

3016. Lovell, P. M., Jr., A comparison of the lateral controllability with flap and plug ailerons on a sweptback-wing model having full-span flaps, *Nat. adv. Comm. Aero. tech. Note* 2247, 22 pp., Dec. 1950.

Model had a 38° sweptback wing with an aspect ratio of 3 and a taper ratio of 0.5. Model controllability in free-flight tunnel was satisfactory over entire flight-test range using plug ailerons alone or flap ailerons and rudder. For flights with adequate oscillatory stability, plug ailerons were more satisfactory than ailerons alone. With inadequate oscillatory stability, flap ailerons provided better control than either plug ailerons alone or flap ailerons and rudder. Arthur L. Jones, USA

3017. Hunter-Tod, J. H., and Robinson, A., The aerodynamic derivatives with respect to sideslip for a delta wing with small dihedral at supersonic speeds, *Coll. Aero. Cranfield Rep.* 12, 7 pp., Dec. 1950.

This is an addendum to Rep. 12, 1947 [see AMR **2**, Rev. 1455].

The axis of a delta wing under sideslip is not aligned with that of the apex Mach cone. In calculating the forces by first-order methods, this fact may be ignored when the wing is at zero incidence, but when it is at incidence, first-order effects are introduced due to the distortion of the existing flow. In the original paper the latter were ignored; the corresponding forces are derived in the present addendum.

Neglecting leading-edge suction, the terms in the three sideslip derivatives dependent on incidence are discontinuous in changing from the quasi-subsonic to the definitely supersonic condition, generally involving a marked decrease in the numerical value and, for the rolling derivative, always a change of sign. The leading-edge suction due to incidence drops rapidly to zero as an edge approaches the apex Mach cone, with the result that the suction contributions to the derivatives become indefinitely large in the limiting case, though the actual forces are small.

From authors' summary

3018. **Rogallo, F. M., Lowry, J. G., and Fischel, J., Lateral-control devices suitable for use with full-span flaps,** *J. aero. Sci.* 17, 10, 629–638, Oct. 1950.

A brief history of the development of lateral-control devices suitable for use with full-span flaps is presented with special emphasis on spoiler-type controls. Recent data on the performance of spoiler-type controls on unswept wings at high subsonic speeds and a limited discussion of spoiler controls on swept wings are included. Several advantages shown for spoiler-type controls—high lift through the use of full-span flaps, good aileron effectiveness throughout the speed range, good yawing-moment characteristics, low wing torsional loads, and the possibility of low control forces—appear to warrant their consideration for use on all types of airplanes.

Application of spoiler ailerons as air brakes while simultaneously functioning as ailerons is discussed, and their performance is shown to compare favorably with that of other currently used air brakes.

From authors' summary

3019. **Santangelo, G., A proposition for the evaluation of the maneuverability of airplanes** (in Italian), *Aerotecnica* **29, 5,** 308–316, Nov. 1949.

3020. **Gessow, A., and Amer, K. B., An introduction to the physical aspects of helicopter stability,** *Nat. adv. Comm. Aero. Rep.* 993, 14 pp., 1950.

See AMR **3,** Rev. 1141.

3021. **Amer, K. B., and Gustafson, F. B., Charts for estimation of longitudinal-stability derivatives for a helicopter rotor in forward flight,** *Nat. adv. Comm. Aero. tech. Note* 2309, 51 pp., Mar. 1951.

Charts are presented from which derivatives of important stability parameters can either be read directly, or readily obtained. These derivatives express rate of change of: rotor resultant force, rotor pitching moment, and rotor torque with respect to rotor angle of attack, forward speed, rotor speed, and collective pitch. Derivatives with respect to pitching velocity are omitted, but reference is given to a source of this information. Influence of cyclic pitch is not considered, and the whole analysis is made for flat, rectangular blades with flapping hinges at rotor axis. In spite of these simplifications, the work may be useful in solving longitudinal stability and associated problems of almost all practical rotors (tapered, twisted blades, moderately offset hinges).

Authors emphasize that they did not rely upon the assumption (which may lead to appreciable errors) that the rotor resultant-force vector is perpendicular to tip-path plane, thus implying that this is usually assumed in practice. However, reviewer believes that it is rather normally assumed that not the whole resultant vector, but only its component due to lift of blade elements is perpendicular to tip-path plane, while component due to profile drag lies in the plane. The above approach, although simplifying analysis, should not lead to degree of discrepancy resulting from the aforementioned assumptions. W. Z. Stepniewski, USA

3022. **O'Hara, F., Flight testing of helicopters,** *J. Helicop. Assn.* **4,** 1, 2–27, Apr., May, June 1950.

3023. **Greidanus, J. H., and van de Vooren, A. I., Gust load coefficients for wing and tail surfaces of an aeroplane,** *Nat. LuchtLab. Amsterdam Rap.* F.28, 12 pp., 1951.

Utilizing the three general equations of motion of the airplane and assuming the distribution of gust velocity along the flight path, author calculates gust-load coefficients as a function of various airplane parameters. The results, omitting derivations and calculations, are presented in a series of charts.

A. Petroff, USA

3024. **Press, H., The application of the statistical theory of extreme values to gust-load problems,** *Nat. adv. Comm. Aero. Rep.* 991, 16 pp., 1950.

See AMR **4,** Rev. 371.

3025. **Lyon, H. M., and Ripley, J., A general survey of the effects of flexibility of the fuselage, tail unit and control systems on longitudinal stability and control,** *Aero. Res. Counc. Lond. Rep. Mem.* 2415, 69 pp., July 1945, published 1950.

Effect of the flexibility of fuselage, tail, and control system on longitudinal stability and control is studied, and extensive charts showing the effects are presented. These results are based upon theory developed [in *Rep. Mem.* 2027] by Gates and Lyon, which neglects the time lag in elastic deformation and uses strip theory in estimating aerodynamic loads. The following types of distortion are studied in considerable detail: Elevator control system stretch, tab distortion, fuselage bending, tail-plane twist, elevator twist, and elevator-skin distortion. In addition, some examples of interacting types of distortion, such as combined tail-plane and elevator twist, are studied. Results are presented as extensive tables and graphs, showing effects of these deformations on static stability and control as well as on maneuverability. Appearing over five years after writing, report has lost some of its value, due to large changes in aircraft design made during this period.

Wilbur L. Mitchell, USA

3026. **Goodman, A., and Fisher, L. R., Investigation at low speeds of the effect of aspect ratio and sweep on rolling stability derivatives of untapered wings,** *Nat. adv. Comm. Aero. Rep.* 968, 11 pp., 1950.

See AMR **3,** Rev. 1140.

Aeroelasticity (Flutter, Divergence, etc.)

(See also Revs. 3007, 3029)

3027. **Williams, J., Expansion method for flutter equations,** *Aero. Quart.* **2,** part 3, 209–225, Nov. 1950.

Part I is concerned with a modification of Frazer's framework method [*Proc. roy. Soc. Lond. Ser. A.*, **185,** p. 465, 1946] for indirect expansion of flutter and stability determinants. Numerical values of flutter determinant for n-degree-of-freedom system must be computed for $\frac{1}{2}(n + 1)(n + 2)$ pairs of values of flutter parameters. Improved accuracy is achieved by employing framework of lines with all intersections inside flutter quadrant. A method is outlined for numerical solution of expanded equation; details of computational scheme are presented in Appendix I. Framework methods are limited to analyses in which air loads are approximated by classical derivative theory.

Applications of standard univariate interpolation formulas and of generalized Gregory-Newton formula for bivariate interpolation are discussed in part II. Univariate formulas may be used in

analyses employing tabulated aerodynamic data (e.g., coefficients calculated from vortex sheet theory), requiring determinant expansions for assigned values of the frequency parameter. In applications of classical derivative theory, bivariate interpolation methods may give better accuracy than framework methods, as collocation points can be regularly spaced, but computational work is greater. M. J. Turner, USA

3028. Frazer, R. A., Graphical treatment of binary mass-balancing problems, *Aero. Res. Counc. Lond. Rep. Mem.* 2551, 10 pp., Aug. 1942, publ. 1951.

Method based on classical derivative theory and leading to stability diagrams for binary systems is described. For flexural-aileron and torsional-aileron flutter, coordinates in diagrams are dimensionless product of inertia coefficient and aileron moment of inertia coefficient. For aileron-spring-tab and servo-rudder flutter, coordinates are coefficients replacing product of inertia and tab moments of inertia after transformation has been performed, which brings elastic matrix to diagonal form. Stability boundary depends only on aerodynamic coefficients. System will be stable for all stiffness values if inertia point lies at safe side of stability boundary. Points at unsafe side will nearly always correspond to unstable systems, though in exceptional cases the system may still be absolutely stable. Stability boundary is formed by one branch of hyperbola which may conservatively be approximated by asymptote.

Chief advantage is easy judgment of influence of variations in mass and in air density, since such variations correspond to changes in inertia point without changing stability boundary.

A. I. van de Vooren, Holland

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 2837, 3020, 3048, 3073, 3100)

3029. Roberts, J. C., and Yaggy, P. F., A survey of the flow at the plane of the propeller of a twin-engine airplane, *Nat. adv. Comm. Aero. tech. Note* 2192, 178 pp., Sept. 1950.

Air flow at the propeller plane of a full-scale twin-engine airplane was surveyed to provide data for use in calculation of oscillating aerodynamic loadings on propellers. Investigation was conducted throughout an angle-of-attack range of 0° to 10° for two nacelle-inlet mass-flow ratios. Data were obtained for wing-flap deflections of 0° and 40° for each nacelle-inlet mass-flow ratio. Results are presented in form of following parameters: Ratio of local velocity to free-stream velocity, and angles defining direction of local velocity relative to survey disk. A comparison is made between measured upwash angles and those calculated for the wing by use of lifting-line theory. Effect of flow field on oscillating aerodynamic loading on a propeller is indicated. Method of using flow-field data in calculating this loading is given in appendix.

Measured upwash angles were much larger than the calculated wing-induced upwash angles. Thus, it appears that nacelle and fuselage were responsible for a large portion of upwash. Since similar results would be expected for other wing-fuselage-nacelle combinations, the importance of developing a method of predicting the contributions of nacelles and fuselages is evident. With the partial-span wing flaps deflected, the rate of change of upwash angle with lift coefficient was about the same as with the flaps undeflected; at a given lift coefficient, however, the upwash angle was less with the flaps deflected.

Changing the nacelle-inlet mass-flow ratio from about 0.14 to 0.29 had a sizable effect on only that part of the flow field immediately in front of the nacelle, and hence the change does not appear significant from the standpoint of the oscillating aerodynamic loading on a propeller. From authors' summary

3030. Traupel, W., Compressible flow through turbines (in German), *Schweiz. Arch.* 16, 5, 6: 129–138, 176–186; May, June, 1950.

Theory is developed for mathematical treatment of flow through axial-flow turbines and compressors when compressibility effects are important. Prime importance is attached to questions concerned with radial equilibrium, and magnitude of compressibility effects on flow pattern are shown to depend greatly on radial distribution of density. Theory is limited by usual assumptions of frictionless flow and isentropic processes. Although paper contains little of direct application to design of axial-flow machines, it is of interest from a theoretical standpoint.

C. W. Smith, USA

3031. Siestrunck, R., and Fabri, J., Whirling flow in axial machines (in French), *Off. Nat. Étud. Rech. aéro. Publ.* 45, 64 pp., Dec. 1950.

Authors characterize the flow in axial machines by means of two functions: Stream function satisfying the continuity relation, and moment of momentum with respect to axis of rotation of machine. By admitting infinite blade numbers in each blade row and neglecting axial length of rows, the blading is reduced to a succession of "vortex disks." A general two-dimensional relation for compressible vortex flow is established between the stream and momentum functions. A linearized solution is worked out for the case of incompressible flow. The experimental deflection curves from cascade tests can be introduced in this solution and several examples of nonpotential flow are calculated. Interesting conclusions are drawn with respect to difference in deflections of grids in two-dimensional cascade tests and three-dimensional flow in machines. Multistage arrangements are discussed also under conditions different from design point. Last chapter shows some calculations for compressible flow.

Reviewer considers paper a very valuable contribution, though further simplifications should be introduced for practical application. Furthermore, there is definite need to take induced losses into account. E. Haenni, Switzerland

3032. Lieblein, S., and Sandercock, D. M., Compressibility correction for turning angles of axial-flow inlet guide vanes, *Nat. adv. Comm. Aero. tech. Note* 2215, 31 pp., Dec. 1950.

Simplified extension of Prandtl-Glauert compressibility correction for isolated airfoils is obtained for airfoils in cascade with axial air inlet (accelerating flow) by considering total lift coefficient of cascade to be sum of two components. One is associated with a velocity of constant magnitude across cascade; the other is associated with change in velocity across cascade. From the hypothesis, an analytical variation of lift coefficient and air-turning angle with inlet Mach number at fixed angle of attack is obtained for two-dimensional flow; adaptation is then made for annular flow. Agreement is found with limited experimental data.

From authors' summary by H. S. Ribner, USA

3033. Fontaine, M., The measurement of hydraulic turbine efficiency by the thermometrical method (in French), *Houille blanche* 6, 1, 12–22, Jan.-Feb. 1951.

After describing the method and showing that only by means of precise temperature measurements of water can efficiency of water turbines be determined, author gives results of some tests which agree very well with results of other methods (weir and current-meter gagings). Good accuracy was obtained even on heads as low as 1 to 7 m.

Application to pumps—which are even more suitable to this method—and measurement of labyrinth losses in a Francis turbine as example of special application are then described. Method can be very useful in many cases, but, in reviewer' sopinion, its importance is reduced by the fact that it fails when cavitation occurs. M. Nechleba, Czechoslovakia

3034. **Pattantyús, G., Approximate design of the characteristic curve of axial-flow (propeller) pumps from the velocity diagram,** *Müeg. Közl.*, no. 1, 51–57, 1949.

3035. **Sänger, E., On the theory of the stationary and pulsating ramjet engine** (in German), *Schweiz. Arch.* **16,** 11, 12; 341–352, 369–378; Nov., Dec. 1950.

Theory of ramjets based on frictionless, one-dimensional flow and on constant gas properties which are different before and after combustion is developed. Average velocities over the cross section are used. Addition of the mass of the fuel is taken into account. Thrust and efficiency of ramjets with cylindrical and with variable cross sections are calculated. Effects of different diffuser types are also considered. A brief historical sketch of ramjet development is followed by the analysis of subsonic and supersonic diffusers. The theory of diabatic steady and pulsating flows in ducts with heat addition is developed. In particular, it is shown that at a certain value of heat addition, transition from steady to pulsating flow occurs. Flow equations for subsonic and supersonic nozzles are given. Method of calculations for external and internal diffusers is discussed next. Then, internal drag is considered. In the last part, it is shown that at low subsonic velocities, thrust and efficiency are considerably higher if the combustion chamber pressures are raised (e.g., through intermittent operation, or by means of compressors, as in the case of the turbojets). However, from a flight Mach number of three on, the steady-flow ramjet seems to be the best power plant. Although much more work will have to be done in this field in order that the influence of viscosity, turbulence, variation of gas properties during combustion, etc., can be incorporated in a complete theory of ramjets, paper is one of the best existing treatments of one-dimensional flows with heat addition. It is recommended to every worker in the ramjet and rocket fields.

Paul Torda, USA

Flow and Flight Test Techniques

(See also Revs. 2799, 2980, 3006, 3008, 3016, 3017, 3029, 3089)

3036. **Brandin, T., Performance of wind tunnels** (in Swedish), *Tekn. Tidsk.* **79,** 38, 765–766, Oct. 22, 1949.

3037. **Whitehead, L. G., Wu, L. Y., and Waters, M. H. L., Contracting ducts of finite length,** *Aero. Quart.* **2,** part 4, 254–271, Feb. 1951.

A method of designing wind-tunnel contractions is given for frictionless flow at low speeds with compressibility effects neglected. Two-dimensional designs are obtained by solving for in hodograph plane. By using the stream function and velocity potential of the two-dimensional flow, an approximate solution is given for axially symmetric flow. The effects of the parallel sections upstream and downstream of the contraction are investigated by the authors. G. V. R. Rao, USA

3038. **Fauquet, A., Measurement of a pressure slightly sensitive to direction and to Reynolds numbers** (in French), *C. R. Acad. Sci. Paris* **230,** 7, 616–617, Feb. 1950.

3039. **van der Hegge Zijnen, B. G., On the construction of hot-wire anemometers for the investigation of turbulence,** *Appl. sci. Res. Sec. A*, **2,** 5–6, 351–363, 1951.

Paper reviews principal trends and construction methods for hot-wire anemometers to investigate turbulence. Conclusions are made concerning desirable hot-wire characteristics, such as wire length, diameter, and support dimensions. Hot-wire construction methods developed by the Royal Dutch/Shell Laboratory at Delft are discussed. Description is given of improved spot welding for tungsten wire used at Delft.

Frank L. Wattendorf, USA

3040. **Dätwyler, G., New measuring methods for the hot-wire anemometer** (in French), *C. R. Acad. Sci. Paris* **231,** 19, 945–947, Nov. 1950.

Three new techniques for the hot-wire anemometer are described. In the first, a number of intensity, u', measurements are made with a given time constant, M, setting, and various heating currents. A graphical procedure determines which u' corresponds to the correct M. The second technique determines M by superimposing an alternating current on a hot wire which is not in a bridge circuit. In the third technique, a nearly direct measurement of u' is obtained by doubling, with a known alternating current across the probe, the power output of the amplifier. A bridge circuit is necessary. Robert S. Levine, USA

3041. **Umstätter, H., Viscosity measurements. I. Principles** (in German), *Arch. tech. Messen* no. 178, V 9122-6, T 129–130, Nov. 1950.

In this first of a series of articles on the measurement of viscosity author presents no new material but reviews researches dealing with effects of relaxation time, velocity gradient, temperature, pressure, and concentration on the viscosity of fluids, particularly those of non-Newtonian type. Numerous references to fundamental work of the author and others are presented. Understanding of equations is complicated by the occasional use of undefined symbols. Charles D. Strang, Jr., USA

3042. **Umstätter, H., Viscosity measurements. II. Measuring instruments** (in German), *Arch. tech. Messen* no. 179, T 136-T 138, Dec. 1950.

Author describes a number of special viscosimeters for determination of viscosity as a function of time, velocity gradient, pressure, temperature, and concentration.

Charles D. Strang, Jr., USA

3043. **Bardsley, O., The conditions at a sharp leading edge in supersonic flow,** *Phil. Mag.* (7) **42,** 326, 255–262, Mar. 1951.

Paper describes experiments designed to investigate supersonic flow past a knife edge at a high incidence producing an expansion region on one side. Schlieren photographs show a weak shock wave, not predicted by inviscid theory, forming immediately upstream of the expansion zone. Experiments were conducted in an intermittent supersonic wind tunnel at a mean Mach number of 1.965, using a wedge of 10° apex angle and having an average thickness of 8μ at leading edge. Photographs show deterioration of leading edge during a two-minute run, believed caused by dust in air stream. Mathematical analyses are presented which suggest that the weak shock is not a result of boundary-layer growth at leading edge. Furthermore, photographs do not substantiate the assumption of boundary-layer separation in causing shock. Computing the shock-wave strength from the inclination of the weak shock measured from the photographs and comparing with the theoretical relation between shock-wave strength and leading-edge thickness result in shock strengths of

same order of magnitude. Conclusion is thus reached that the observed weak shock in the expansion region is caused probably by the slight bluntness of the leading edge.

Charles E. Carver, Jr., USA

3044. Rogers, E. W. E., and Berry, C. J., Tests on the effect of incidence on some pressure heads at high subsonic speeds, *Aero. Res. Counc. Lond. curr. Pap.* 41, 6 pp., July 1950.

Tunnel measurements have shown that up to at least $M = 0.75$, loss in total head on a Venturi-shrouded Pitot was less than 0.5% for incidences of up to about 40°. This compares with a limit of 9° at $M = 0.7$ to 0.85 for 0.5% loss on the Pitot section of a standard Mk. VIIIA instrument and 17° at $M = 0.7$ to 0.9 on the small Pitot heads in general use in the N.P.L. high-speed tunnels. The corresponding incidence limit for the static side of the Mk. VIIIA instrument was about 7°, compared with 5° for the standard tunnel static tube. From authors' summary

3045. Fletcher, P. J., A three-channel piezo-electric pressure recorder, *Aero. Res. Counc. Lond. curr. Pap.* 35, 5 pp., Nov. 1949, published 1951.

To speed up operation of a low-speed cascade tunnel, an apparatus has been constructed to record the pressures needed for "loss coefficients." The pressures are: upstream total head, downstream total head, and downstream static pressure. An electrical method of recording has been chosen because of the ease with which the sensitivity can be varied to accommodate a large tunnel speed range. A diaphragm-loaded quartz crystal is used as the pressure sensitive element.

The signal from the crystal is indicated on a cathode-ray oscilloscope and recorded by a 35-mm moving film camera. To record the three pressures concurrently, they are connected in sequence by a rotary valve to the quartz-crystal pickup, and the potential produced amplified by long time-constant circuits. Linearity of indication is satisfactory, but there is a slight air leakage due to the air capacity of the pickup and care must be taken to insure that the error due to this is within desired limits.

From author's summary

Thermodynamics

(See also Rev. 2789)

3046. Rozen, A. M., Adiabatic process of compression of real gases, *Doklady Akad. Nauk SSSR (N.S.)* **70,** 3, 413–416, Jan. 1950.

3047. Gilles, P. W., and Wheatley, Q. de L., The thermodynamic properties of gaseous titanium, *J. chem. Phys.* **19,** 1, 129–130, Jan. 1951.

Values of zero-pressure free energy, enthalpy, entropy, and specific heat at constant pressure are given for neutral titanium vapor for temperatures from 10 to 5000 K. They were calculated by authors from atomic energy levels published in 1949 by C. E. Moore in NBS Circular 467. The specific heat is 4.9680 cal/K mole at 10 K, passes through a maximum of 6.578 at 135 K, a minimum of 5.096 at 990 K, and increases to 9.708 at 5000 K, a type of behavior previously noted in gaseous iron. Agreement with previous calculations is good. Joseph H. Keenan, USA

3048. Gunder, D. F., and Friant, D. R., Stability of flow in a rocket motor, *J. appl. Mech.* **17,** 3, 327–333, Sept. 1950.

Paper presents an analytical treatment of one type of pressure pulsation, a type known as "chugging," that can occur in a liquid-propellant-fed rocket engine. A simple, monopropellant system with combustion at a single point in the chamber is assumed. The model analyzed is based on the following sequence: (a) A momentary decrease in the propellant flow; (b) shortly thereafter a decrease in the rate of burning at the point of combustion; (c) a decrease in pressure at the point of combustion; (d) a spread of this pressure wave to the injector where it causes increased propellant flow; (e) shortly thereafter, an increase in the burning rate that increases pressure and thus decreases propellant flow again: and the cycle continues, with the propellant velocity and combustor pressure pulsating.

The equation of motion for the pulsating system is written as a differential equation in terms of a variation of the propellant-flow velocity from the steady-state velocity. Four methods of solving this equation are discussed. One of these solutions, a conformal transformation, yields a criterion for the stability of the system in terms of the system geometry, propellant-flow rate, and combustion-chamber pressure. W. T. Olson, USA

3049. Daub, W. E., Theory of emission-propulsion accomplished without atmospheric oxygen (in Spanish), *Tecnica y Economia*, no. 2, 27–32, Dec. 1949.

3050. Heal, H. T., and Mykura, H., An X-ray method for the study of phase changes at high temperatures, *Metal Treatm.* 17, 63, 129–135, Autumn 1950.

A method of studying phase transformations in solids by continuously measuring the intensity of x-rays diffracted from one set of crystal planes is described. It uses a bent-crystal monochromator, Seemann-Bohlin focusing, and a Geiger counter as detector. Counter output is recorded via a counting-rate meter, a double-beam monitoring system being used to compensate for fluctuations in x-ray output. An S curve for a 2½% Ni steel, determined by this method, is given, and shows fair agreement with curves for the same steel obtained by the standard microscopic technique. Fast cooling from 750 C down to the temperature at which the isothermal transformation is investigated is achieved by using very thin (0.1) mm steel sheets which cool in vacuum in a few seconds due to their own radiation. Method has the advantage that it can be applied to transformation studies during continuous cooling and in the martensite region, where other methods become difficult. Also, in transformations where more than two phases appear, observations can be made directly on the separate phases. K. W. Taconis, Netherlands

3051. Michels, A., Skelton, G. F., and Dumoulin, E., Gas-liquid phase equilibrium in the system ammonia-hydrogen-nitrogen, *Physica*, **16,** 11–12, 831–838, Dec. 1950.

Authors developed a device for use in studies of gas-liquid equilibria at high pressures. Equilibrium is developed in a static system, then pressure is maintained constant to 1 part in 100,000 during slow withdrawal of samples of liquid and of vapor. The device was tested in a study of the technically important physical equilibria between ammonia and 3:1 hydrogen-nitrogen synthesis gas mixtures. Pressures and temperatures are varied only through ranges of 10 to 800 atm and 0 to 120 C, although the new device is not inherently limited to these ranges. Description of, operating technique for, and experimental results from the new device are given. It is found that the ammonia-synthesis gas system can show retrograde condensation under proper conditions. J. D. Bush, USA

3052. Elser, K., and Hoch, M., Behaviour of various gases and the separation of gas mixtures in a vortex tube (in German), *Z. Naturforsch.* **6a,** 1, 25–31, Jan. 1951.

The energy of a gas (indicated by its total temperature) in a

vortex flow is smaller near the center and higher near the rim. This effect, discovered by Ranque (Ranque effect), can be used in a vortex tube (Hilsch tube) to separate a gas blown through a nozzle into the tube tangentially into a low temperature and a high temperature stream. Present report studies this effect on air, hydrogen, argon, methane, and carbon dioxide in such a vortex tube and its dependence on nozzle pressure and temperature. It is concluded that the effect has to be explained from a gas-kinetic viewpoint. The effect was also observed—although to a minor degree—in the mixing region of air jets emerging from a register of staggered nozzles. (It is also present in boundary-layer flow with high velocities.) In a vortex tube, also, a separation of gas mixtures takes place, the concentration of the heavier gas being greater near the axis. Air blown through a vortex tube has approximately 1 vol % more oxygen and combustion gas has approximately 1 vol % more carbon dioxide in the cold stream than in the warm stream. It is proposed to utilize this effect for the separation of gas mixtures. E. R. G. Eckert, USA

3053. **Haase, R., On the thermodynamics of fluid mixtures of three substances** (in German), *Z. Naturforsch.* **4a**, 5, 342–352, Aug. 1949.

3054. **Bordoni, P. G., Deduction from statistical mechanics of a law of dependence of the compressibility of solids on temperature** (in Italian), *Atti Accad. Naz. Lincei Rend. Cl. Sci. Fis. Mat. Nat.* 6, 5, 597–602, May 1949.

Heat and Mass Transfer

(See also Revs. 2864, 2951, 2969)

3055. **Blok, H., The dissipation of frictional heat** (in Dutch), *Voordr. Konink. Inst. Ing.* (Oosthoek, Utrecht), no. 1, 84–104, Jan. 1950.

For control of maximum temperature induced either by heat of solid friction in contact areas on rubbing surfaces of machine parts or by heat of fluid friction as generated, for instance, in liquid film separating such surfaces, two kinds of heat dissipation have to be considered, viz.: primary and secondary dissipation. Whereas secondary dissipation is already sufficiently known, although currently only under the more common name of "cooling," primary dissipation is relatively little known. Therefore, paper deals almost exclusively with primary dissipation, and particularly with its influence on maximum temperature in the very source of heat generation.

Primary dissipation, which in numerous cases (e.g. highly loaded gears) is much more important than secondary dissipation, is defined as that stage of dissipation which, in the case of solid friction, is localized in the solid material in the immediate vicinity of the contact area and which, in case of fluid friction, is localized in flowing fluid that acts as source of frictional heat. Both cases of primary dissipation are illustrated by various detailed examples. From author's summary

3056. **Iuchak, G., and Langstroth, G. O., Applications of diffusion theory to evaporation from droplets and flat surfaces,** *Canad. J. Res. Sec. A*, **28**, 6, 574–579, Nov. 1950.

Authors investigate problem of mass transfer into space above a volatile liquid and include the effect of mass transfer on the movement of the surface. Problem is introduced by exact analysis of diffusion of vapor into an infinite space above a liquid surface.

An analysis is then made of the diffusion of vapor into a space bounded by an absorbing surface parallel to the liquid surface at a finite distance away. Rate of loss of mass from surface is calculated in a rigorous fashion and results compared with rate of loss calculated on the assumption of a quasi-stationary state. Authors' results indicate good agreement for water.

Evaporation from droplet is dealt with in similar manner. An iteration method is used to obtain rate of change of radius of droplet and compared with the rate of change obtained by assumption of quasi-stationary state. Authors support correctness of iteration method by comparing form of correction factor obtained for droplet with that obtained for a flat surface. Limitations on range of applicability are indicated.

William A. Wolfe, Canada

3057. **Waeselynck, R., The optimum heat exchanger** (in French), *Bull. Assn. tech. Marit. aéro.* no. 46, 773–802, 1947.

3058. **Kays, W. M., and London, A. L., Heat transfer and flow-friction characteristics of some compact heat-exchanger surfaces, I, II,** *Trans. Amer. Soc. mech. Engrs.* **72**, 8, 1075–1097, Nov. 1950.

Paper describes a test apparatus and method of analysis used for accurate determination of the basic heat-transfer and flow-friction characteristics of compact heat-exchanger surfaces. Experimental accuracy is discussed and results of test of a typical louvered-plate-fin heat-exchanger surface are included to illustrate the quality of data obtainable. It is hoped that the experience presented here may lead to a standardization of test methods so that more accurate design data will be forthcoming.

In part II, paper presents basic heat-transfer and flow-friction design data for thirteen such surfaces, which may be described generally as the plate-fin type and finned-flat-tube type. In addition to the use of the conventional nondimensional correlations, the various surfaces are compared on heat-transfer coefficient vs flow-friction-horsepower basis.

From authors' summary

3059. **Livingood, J. N. B., and Brown, W. B., Analysis of spanwise temperature distribution in three types of air-cooled turbine blade,** *Nat. adv. Comm. Aero. Rep.* 994, 18 pp., 1950.

Methods for computing spanwise blade-temperature distributions are derived for air-cooled hollow blades, air-cooled hollow blades with inserts, and air-cooled blades containing internal cooling fins. Individual and combined effects on spanwise blade-temperature distributions of cooling-air-temperature change due to heat transfer and rotation, radiation, and radial heat conduction are determined. In general, the effects of radiation and radial heat conduction were found to be small and the omission of these variations permitted construction of nondimensional charts for use in determining spanwise temperature distributions through air-cooled turbine blades.

An approximate method for determining the allowable stress-limited blade-temperature distribution is included, with brief accounts of a method for determining the maximum allowable effective gas temperatures and the cooling-air requirements. Numerical examples illustrating the use of the various temperature-distribution equations and of the nondimensional charts are also included.

From authors' summary by W. M. Rohsenow, USA

3060. **Kudryashov, L. I., Approximate solution of the heat transfer problem in free flow with a laminar boundary layer near the wall** (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk*, no. 2, 253–260, Feb. 1951.

Problem treated is that of a viscous fluid adjacent to a heated body kept at constant temperature. Inertia terms in the equa-

tion of motion are neglected, and the equation of heat convection is replaced by an integral relation. In addition, temperature distribution across the boundary layer is assumed to be linear, while the lifting force acting on the fluid is supposed to be independent of the local temperature. Author treats the cases of a vertical plate, a horizontal cylinder, and a sphere, and obtains for the combination $Nu/(GrPr)^{1/4}$ of the Nusselt, Grashof, and Prandtl numbers, respectively, the values 0.55, 0.51, and 0.54. The cited experimental results [title source, no. 10, 1947, and no. 2, 1950] agree well with these values.

A. von Baranoff, France

3061. Prins, J. A., Mulder, J., and Schenk, J., Heat transfer in laminar flow between parallel plates, *Appl. sci. Res. Sec. A*, **2,** 5–6, 431–438, 1951.

Temperature distribution is calculated for flow between infinite parallel plates which have an abrupt temperature change in a plane perpendicular to the plates. The classical equation for stationary heat flow, assuming only transversal heat conduction and longitudinal heat convection, is solved by means of a set of eigenfunctions. Calculations are carried out for the first three eigenvalues, and results in terms of both the "transport mean" temperature and the Nusselt number are compared with results obtained for the Graetz problem for flow in a cylindrical tube. Effect of the dimensions of a heat exchanger on its heat capacity and pressure loss are clearly shown. Mean flow velocity is independent of the distance between the plates, and for any given fluid is dependent only on the pressure loss allowed. For a given cross section corresponding to a given heat-exchange capacity at a given pressure loss, the length may be indefinitely reduced by increasing the number of plates and reducing the separating distance.

Ione D. V. Faro, USA

3062. Daunt, J. G., and Mendelssohn, K., Film transfer in Helium II: I—The thermo-mechanical effect, *Proc. phys. Soc. Lond. Sec. A*, **63,** part 12, 372A, 1305–1312, Dec. 1950.

The thermo-mechanical effect, which was discovered in liquid Helium II in 1937, is studied in the following experimental arrangement: A small Dewar vessel filled with liquid He II is placed into a cryostat filled with the same liquid in such a way that there is no direct connection between both liquids. However, it is known that a film of He covers all solid surfaces in contact with the liquid; that a flow arises within this film when there is a difference in the liquid levels; and that this flow equalizes the levels in a short time. In the experiments, the film surface connecting the two levels was artificially increased by a hook made from twisted wires. When liquid inside the vessel was heated by an electric coil, then the liquid level inside the vessel rose to a level higher than outside. The level difference was found to increase linearly with the heat input at first, then to level off and, finally, to drop toward zero. In the last stage, no equilibrium state existed, the He evaporating faster in the vessel than being supplied through the film. The experiments suggest a critical maximum flow rate in the film, which is calculated and found to agree well with values determined in different ways.

E. R. G. Eckert, USA

3063. Brown, J. B., and Mendelssohn, K., Film transfer in helium II: II—Influence of geometrical form and temperature gradient, *Proc. phys. Soc. Lond. Sec. A*, **63,** part 12, 372A, 1312–1318, Dec. 1950.

Solid surfaces which are in contact with liquid Helium II are covered with a liquid film. When such a film connects liquid He at different level, a flow arises which has no apparent viscous forces (superfluidity). Usually it has been observed that the rate of fluid transfer along the film is a constant at a given temperature and not dependent on the level difference. In some cases, however, observers have noted unusually high flow rates. In order to clarify the situation, experiments were conducted with different arrangements under isothermal conditions and with a temperature gradient in the film. All resulted in the same flow rate, except in some spurious unexplained cases.

E. R. G. Eckert, USA

3064. Bowers, R., and Mendelssohn, K., Film transfer in Helium II: III—Influence of radiation and impurities, *Proc. phys. Soc. Lond. Sec. A*, **63,** part 12, 372A, 1318–1327, Dec. 1950.

Experiments are reported which concern the transfer rate of liquid Helium II through a film of He which covers all solid surfaces in contact with the liquid. Authors had previously postulated that the flow rate is a constant for any temperature. On the other hand, much higher flow rates than the mentioned critical value have been observed occasionally. In a first set of experiments it is shown that presence or absence of heat radiation does not influence flow rate. A second set of tests proves very definitely that high flow rates, when they were observed, were caused by impurities which enter the setup easily with gaseous He and which cause a contamination of the solid surfaces in contact with the liquid He.

E. R. G. Eckert, USA

Acoustics

(See also Revs. 2821, 3096)

3065. Moen, C. J., Ultrasonic absorption in liquids, *J. acoust. Soc. Amer.* **23,** 1, 62–70, Jan. 1951.

Acoustic absorption coefficients were measured for glycerol, water, benzene, carbon bisulfide, and toluene over various frequency ranges in the hundreds of kilocycles, to a minimum of 140 kc. Reverberation method used here (and by others) depends on decay time of acoustical disturbance introduced into spherical chamber. It is described in some detail, as are calculations, results, and sources of error. Results are compared with other accepted values (general agreement), with classical theory of Stokes (glycerol agrees), and with recent modified theories involving relaxation effects (water, benzene agree). Further study of other two liquids is suggested.

A. O. Williams, Jr., USA

3066. Sheehy, M. J., Transmission of 24-kc underwater sound from a deep source, *J. acoust. Soc. Amer.* **22,** 1, 24–28, Jan. 1950.

A few experiments are reported in which thirty-millisecond signals of 24-kc sound were emitted in the ocean every second at depths of 150, 300, 500, and 1000 ft, by a relatively nondirectional projector, and were received by similar units at same depths after having traveled 100 to 3000 yds. A recording technique was used which made it possible to resolve the direct and surface-reflected components. Transmission conditions near surface were poor during the experiments, and transmission was found to improve as projector and receiver depths increased. Average attenuation at greatest depths was about 6 db/1000 yd in addition to loss caused by an assumed inverse-square divergence of sound energy. Although emitted signals had rectangular envelopes and were all of same amplitude, amplitudes of received signals fluctuated from signal to signal and within each signal. Fluctuation of directly transmitted signals showed a general tendency to increase with range in proportion to the square root of the range. Magnitude of this fluctuation changed from about 10% of the average amplitude at 100 yd to 45% at 3000 yd. Fluctuation of the surface-reflected component was greater than that of direct component and did not depend on range.

From author's summary

3067. **Horton, C. W., and Karal, F. C., Jr., On the diffraction of a plane sound wave by a paraboloid of revolution,** *J. acoust. Soc. Amer.* **22,** 6, 855–856, Nov. 1950.

Authors discuss diffraction of plane sound wave at boundary in form of paraboloid of revolution. Two cases are given: (a) interior of paraboloid filled with medium with different density and velocity of sound, and (b) paraboloid is a rigid boundary. A formal solution is given in terms of paraboloidal orthogonal functions (related to confluent hypergeometric functions, Whittaker and Watson, "Modern analysis," ch. 16). Numerical results, except in a simplified problem, are not given but are promised in a later paper. J. W. Jackson, Scotland

3068. **Kharkevich, A. A., Nonstationary problem of diffraction of a plane wave from a rectilinear boundary** (in Russian), *Zh. tekn. Fiz.*, **19,** 828–832, 1949.

A plane pressure wave (unit potential behind the wave front, zero potential before it) is propagated with velocity c over a rigid half-plane screen whose edge is parallel to the wave front. Problem is to determine the pressure at points in the diffraction zone, which in author's theory is an expanding cylindrical region, axis the edge of the half plane and radius ct. By means of the transformation $\cosh z = ct/r$ he finds a solution in the form of a Fourier series. He considers separately the cases in which the wave moves (1) parallel to the half plane, (2) perpendicular to it, and (3) at an arbitrary angle. In the first two of these cases the series is summed explicitly and diagrams are drawn illustrating equipotentials.

Courtesy of Mathematical Reviews F. V. Atkinson, Nigeria

3069. **Kharkevich, A. A., On the construction of qualitative diffraction charts** (in Russian), *Zh. tekn. Fiz.* **19,** 822–827, 1949.

Considering the impact upon an obstacle of an acoustic wave moving with velocity c, author derives by physical arguments a principle to the effect that $\int p dV$ (p the excess pressure, dV the volume element), taken over the field reached by the wave, depends only on the source and not on the obstacle. For certain cases involving symmetry it is maintained that the principle applies to any pair of symmetrically placed volume elements, this leading to certain symmetry properties of the field. The resulting information is regarded as supplementary to charts illustrating the progress of the wave fronts according to Huygen's principle; such charts are drawn for particular cases of diffraction by screens with apertures.

Courtesy of Mathematical Reviews F. V. Atkinson, Nigeria

3070. **Samuel, E. W., and Shankland, R. S., The sound field of a Straubel x-cut crystal,** *J. acoust. Soc. Amer.* **22,** 5, 589–592, Sept. 1950.

Streaming patterns in front of 7.5 mc/sec x-cut quartz crystals were determined by measurement of velocities of sugar particles suspended in CCl_4. Comparison of the results with theory show that the sound field is much more uniform in case of Straubel-contoured crystals than in case of square crystals. Evidence in favor of this conclusion has been accumulating slowly for years, but its indecisive nature makes this paper a welcome contribution.

Martin Greenspan, USA

3071. **Lynton, E. A., and Fairbank, H. A., Second sound in He^3-He^4 mixtures,** *Phys. Rev.* **80,** 6, 1043–1046, Dec. 1950.

Second sound describes temperature wave propagated in helium as temperature approaches absolute zero and concentration of superfluid He 2 increases. Theory indicates strong effect of small concentrations of extraneous particles on wave velocity, owing to fact that only atoms of normal fluid can exchange momentum with impurity, here He^3. Comparison of present experimental results with Pomeranchuk theory [*Zh. eksp. teor. Fiz. USSR* **19,** p. 42, 1949] shows agreement with predicted rise in velocity for concentration of He^3 up to 0.1%. At higher concentrations theoretical values are higher, indicating that minimum energy of He^3 occurs for nonzero particle momentum.

Vincent Salmon, USA

Ballistics, Detonics (Explosions)

(See also Revs. 3002, 3048)

3072. **Spells, K. E., Velocities of steel fragments after perforation of steel plate,** *Proc. phys. Soc. Lond. Sec. B,* **64,** part 3, 375 B, 212–218, Mar. 1951.

Residual velocities of mild steel fragments (right square prisms), projected normally against mild steel plates of thickness between 0.21 cm and 0.85 cm were measured. Perforation occurred by removal of a plug larger than the face of the fragment. Experimental results were fitted by the empirical equation $v_r = v_0 \exp(1.142x)$, where v_r is residual velocity, v_0 striking velocity (1469 meters per second), and x is plate thickness in centimeters. Expressions derived from (1) assumption of conservation of momentum before and after impact, and (2) forces based on hydrodynamical considerations are of the same form and do not differ greatly from the measured points. General comments are made on mechanism of penetration. Herbert K. Weiss, USA

3073. **Re, V., Comparison between single and multi-stage rockets** (in Italian), *Riv. maritt. Suppl. tecn.*, 71–77, Dec. 1950.

A comparison is made between the pay loads of a single- and of a multi-stage rocket having the same jet velocity, same final velocity, and same initial mass. Aerodynamic and gravitational forces are neglected.

The expounded formulas are quite correct under these basic hypotheses, but their physical interpretation is erroneous. Author concludes that a single-stage rocket is more convenient than a multi-stage one (!), demonstrating thus the opposite of what is written in the recent and well-known papers of Malina [see AMR **1,** Rev. 153], Summerfield, Seifert, Mills, and others. Finally, the distinction between the concept of weight and the concept of mass is not clear. Angelo Miele, Argentina

3074. **Corner, J., Theory of the interior ballistics of guns,** New York, John Wiley & Sons, Inc., 1950, 443 pp. $8.

This is not merely the sole substantial recent text wholly devoted to the theory of interior ballistics, but it is practically the only book of its kind in the English language. The author emphasizes, as have many workers in the field for the last quarter century, that the complexity of the physical and chemical processes involved, and the still unsolved problems whose solution lies in experimental research, may have rendered obsolete any refined discussion of a mathematical structure based on a few simple physical assumptions. The system of gun, projectile, and charge, while appearing to be one of the simplest of all heat engines, involves thermo-chemical changes and transient physical phenomena still calling for examination. No adequate survey of the rich contents of this excellent book is possible in the compass of a brief review. From the point of view of mathematics, perhaps the interesting features are the use of general methods of fluid mechanics, the similarity relations for a simple set of ballistic equations, the use of numerical integration, and the study of first-order theory and the limitations thereof. For the designer of ordnance and of ammunition, the recently enriched results concerning powder composition, granulation, leaking guns, heat

transfer to the barrel, high-low-pressure guns, and tapered-bore guns, will prove of interest and value. Of course, many facts of military significance remain too confidential for publication in any book available to the general public. A. A. Bennett, USA

3075. Quinn, H. F., McKay, W. B., and Bourque, O. J., A Kerr cell camera and flash illumination unit for ballistic photography, *J. appl. Phys.* **21,** 10, 995–1001, Oct. 1950.

Paper describes an experimental model of a combination Kerr cell camera and flash-illumination unit designed specifically for photography of projectiles under conditions of strong ambient illumination. Specific cases wherein such conditions are found are considered, and applicability of Kerr cell as a secondary protecting shutter is described. A description is given of a pulse-forming network-pulse transformer circuit designed to apply an operating voltage pulse to a Kerr cell of 36 kilovolts amplitude and 1.9 microseconds duration. Limitations inherent in present equipment are considered, together with proposals for overcoming these defects in future models. Typical results are presented, including (a) a picture taken with the unit showing a 20-mm shot at time of emergence from muzzle of a gun, and (b) a picture of 37-mm shot taken shortly after penetration of a metal target plate. From authors' summary

Soil Mechanics, Seepage

(See also Rev. 2990)

3076. Osoba, J. S., Richardson, J. G., Kerver, J. K., Hafford, J. A., and Blair, P. M., Laboratory measurements of relative permeability, *J. Petr. Technol.* **3,** 2, 47–56, Feb. 1951.

Authors investigate five methods for determining the relative permeabilities to oil and gas of small samples of reservoir rock. These are the "Penn State," "the single core dynamic," "the gas drive," "Hassler," and the "stationary liquid" methods. The relative permeability, defined as the ratio of the permeability of a rock for a particular fluid to the permeability for a single phase at 100% saturation, when plotted against degree saturation is found to be essentially the same for gas by all methods. Using oil, for which only the first four methods apply, the first three give comparable results, but the Hassler method gives lower relative permeabilities throughout. Deviations are found where boundary effects are known to exist. Hysteresis effects vary also, depending on whether the saturation is approached from above or below. Eben Vey, USA

3077. Labasse, H., Soil pressure in coal mines, V, VI (in French), *Rev. univ. Min.* (9), **7,** 3, 85–106, Mar. 1951.

Paper forms the 5th and 6th part of author's investigations [AMR **2,** Revs. 1332, 1333; **4,** Rev. 2273]. Deformations in the strata above and adjacent to a worked seam are studied and the observed ground movements above some actual mines are analyzed generally. G. G. Meyerhof, England

3078. Belaenko, F. A., The stresses around a circular shaft in an elastic-plastic soil (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk,* pp. 914–925, 1950.

Consider a deep vertical circular shaft in a homogeneous isotropic soil bounded by a horizontal surface and exhibiting linear hardening in the plastic range. Mathematically, problem is equivalent to a rotationally symmetric half space with an infinitely long hole and a constant body force normal to the free surface. Determination of stresses is reduced to an integration of a second-order ordinary nonlinear differential equation. An approximate solution is given which satisfies the differential equation at the surface of the shaft as well as the boundary conditions. The vertical stress is a function only of the distance from the free surface, and the radial and hoop stresses vary exponentially with the radial distance from the center of the shaft.
Courtesy of Mathematical Reviews H. I. Ansoff, USA

3079. Rietema, K., Survey of filtration theories (in Dutch), *Ingenieur* **63,** 4, Ch 1-Ch 7, Jan. 1951.

This survey of filtration theories starts with a discussion of block filtration (in this case the pores of the filter medium are gradually blocked by fine particles). It is pointed out that no general theory has been found or is to be expected. Then, a thorough discussion of cake filtration is given. In this case, no blocking of pores occurs, but the filtered particles gradually build up a cake resting on the filter medium. A general equation is arrived at, giving a relation between filtration rate and the quantity of filtrate which has passed through the filter. Various disturbing factors (e.g., compressibility of the cake and scouring of fine particles) are discussed. H. C. Brinkman, Indonesia

3080. Galin, L. A., On nonsteady filtration at constant pressure on the boundary (in Russian), *Prikl. Mat. Mekh.* **15,** 1, 111–116, Jan.-Feb. 1951.

Author discusses problem of unsteady filtration of oil in horizontal plane toward the drill hole in conditions of constant pressures both in the hole and on the gradually shrinking boundary. The complex function z mapping the oil region on a unit circle depends on time, and it must satisfy certain conditions derived by the author in his previous paper. By proper selection of functions z, solutions are obtained corresponding to initial regions in the forms of an infinite straight strip and a semi-plane with the drill hole at a finite distance from the edge.
Alexander Hrennikoff, Canada

3081. Foster, C. R., and Fergus, S. M., Stress distribution in a homogeneous soil, with discussion by D. P. Krynine, F. H. Scrivner, and E. S. Barber, *Nat. Res. Counc. Highway Res. Bd., Res. Rep.* 12-F, 36 pp., 1951.

Engineers who have been in doubt concerning the validity of usual pressure-distribution assumptions will find highly significant data in this report. Results of 30,000 stress measurements and 3000 deflection measurements are presented graphically and compared with theoretical values.

Observed values check fairly well with theoretical values in all cases and very closely in the great majority. Distribution pattern is found to agree closely with that computed from theory of elasticity for homogeneous, isotropic material. Stress-strain curves from actual loading have shape similar to those from "quick" triaxial tests. Harold H. Munger, USA

3082. Habib, P., Determination of the modulus of elasticity of rocks on the site (in French), *Ann. Inst. tech. Bât. Trav. publics* (*N.S.*), no. 145, 27–35, Sept. 1950.

After explaining in detail the theory of elasticity of rock, author states principles of method of testing to be used on the site by means of a jack. He describes tests which were carried out on dam at Tignes using this method, and which proved the existence of a true "site modulus of elasticity" which was very different from the modulus of elasticity measured on laboratory specimen and always smaller.

Recommended method is sufficiently accurate and forms basis of mechanical site investigations which are complementary to geological investigation. An appendix gives formulas for defor-

mation of the surface of an elastic, semi-infinite solid under a load applied over a circle. From author's summary

3083. **Odenstad, Sten, Stresses and strains in the undrained compression test,** *Géotechnique Lond.* **1**, 4, 242–249, Dec. 1949.

3084. **Hough, B. K., A universal loading machine for engineering tests on soils,** *Amer. Soc. Test. Mat. Bull.* no. 170, 44–47, Dec. 1950.

Author describes multipurpose testing machine having three separate loading and weighing systems. Compactness is essential feature. Model capable of delivering maximum vertical load of 4000 lb requires 24 × 30-in. floor area, exclusive of compressed air power unit. Unconfined compression, consolidation, triaxial shear, and direct shear tests are handled separately on the working table.

Vertical loading head is equipped with manual and reversible power drive capable of operating within the range 0.100- and 3.0-in. travel per minute. The horizontal loading head is able to produce two-way movement. During the direct shear test, upper and lower parts of the shear box travel in opposite directions simultaneously at equal rates of speed. Again manual and power drives are available, capable of travels within the range 0.050 and 0.500 in./min. Third loading system is used to apply and maintain the lateral pressure on triaxial shear specimens.

Separate weighing devices are provided for each loading system. Essential features of the vertical system are an air-loaded flexible diaphragm and extremely sensitive Bourdon pressure gage. Load indication is to 10 lb with diaphragm midposition accuracy of 2% scale reading, and 4% with diaphragm ±0.025 in. from center position. Pressure regulating and needle bleeder valves are provided for control. Experience indicates that reliability and permanency of calibration of the unit are not affected by diaphragm replacement. Horizontal loads are "weighed" with a proving ring placed in the linkage system.

At least three of these machines are now in laboratory service. It is suggested that their construction permits "following" sample deformation at constant load, thereby duplicating dead-weight beam and platform-scale type machines. Comparative test data necessary to validate these claims are not presented in the paper.

T. L. Speer, USA

3085. **McDowell, J. M., and Muskat, M., The effect on well productivity of formation penetration beyond perforated casing,** *J. Petr. Technol.* **2**, 11, 309–312, Nov. 1950.

Results of laboratory electrolytic model experiments are analyzed and reported in the form of diagrams which give the relationship between (1) ratio Q/Q_0 of productive capacity Q of a cased and perforated well to productive capacity Q_0 of uncased well; (2) penetration depth and type of the perforations; (3) perforation density expressed by number of holes per foot; (4) three different sets of well-diameter and perforation-diameter values. Greater than one Q/Q_0 ratios were found for large depths of penetration.

Gregory P. Tschebotarioff, USA

Micromeritics

(See also Rev. 2921)

3086. **Kiesskalt, S., and Matz, G., On the determination of the specific surface of particle distributions** (in German), *Z. Ver. dtsch. Ing.* **93**, 3, 58–60, Jan. 1951.

Paper demonstrates the plotting of size distributions of various finely divided materials as straight lines on Rosin-Rammler-Bennett coordinates. The slope and mean particle size thus obtained give an evaluation of Rammler's equation for the "idealized specific surface" (surface area of a powder of spheres in m^2/kg). So-called surface tables give a graphical solution for this parameter. Authors re-evaluate Rammler's equation and establish a simple relationship enabling the "true" specific surface to be obtained from the idealized value when the specific gravity and Heywood's shape factor (obtained microscopically) are known. This procedure should be useful if the size-frequency distribution is known with confidence and is of the usual type.

K. R. May, England

3087. **Ratcliffe, A., The particle size analysis of crushed products,** *Proc. Instn. mech. Engrs.* **162**, 3, 378–383, 1950.

Graphical and mathematical examination is made of two particle-size analyses typical of two classes of crushed products, one of limestone reduced in a hammer mill where the product contains a preponderance of smaller sizes; this is characteristic also of ball mill products, where the material is similarly subjected to indiscriminate reduction, and of the small particles in the products of jaw, gyratory, and roll crushers. The second illustrates the influence of the sizing action which occurs in the latter machines resulting in closer grading of coarse fraction. Author concludes that the tooth roll crusher can be designed to give a more closely graded product containing a minimum of oversize and undersize than any other crusher, although the provision of special projecting teeth in a primary roll crusher to insure nipping of large particles in the feed results in a marked increase in the yield of smalls and a wider size distribution of the coarse fraction. A mathematical basis for Gaudin's law of particle size distribution is given.

S. G. Ward, England

3088. **Newman, S., and Eirich, F., Particle shape and the concentration dependence of sedimentation and diffusion,** *J. Colloid Sci.* **5**, 6, 541–549, Dec. 1950.

Sedimentation data were obtained with an air-driven ultracentrifuge on four fractions of polystyrenes in chloroform, toluene, and methyl ethyl ketone, respectively (concentration range 0.01–1.0%). Object was to determine the concentration dependence of the frictional coefficient F per mole of flexible macromolecules from measured values of sedimentation constant s defined by

$$s = \frac{dx/dt}{w^2x} = M(1 - V\rho)/F$$

(M is mol. weight, V partial spec. vol., ρ density of solution, w^2x centrifugal acceleration).

Following others, authors assume $F = F_0(1 + KC)$, so that $s = s_0/(1 + KC)$ if s_0 is the value for zero concentration C.

Experiments showed that, over the range investigated, K is proportional to $M^{1/2}$ and to the average molecular extension. Furthermore, a strong parallelism is found between K and the intrinsic viscosity (measured with an Ostwald-type viscometer) of the suspension (proportionality constant $\cong 1.6$). Since K and the intrinsic viscosity are connected with the molecular weight and the average configurations of the particles, conclusion is drawn from this parallelism that both must depend on the molecular structure in a closely similar way.

J. O. Hinze, Holland

3089. **Iberall, A. S., Permeability of glass wool and other highly porous media,** *J. Res. nat. Bur. Stands.* **45**, 5, 398–406, Nov. 1950.

Flowmeters yielding a pressure drop which is directly proportional to the flow rate can be constructed by using a glass wool

plug. The Reynolds number based on the diameter of the fiber should not exceed 1.

By adding expressions for the drag of single cylinders normal and parallel to the flow, a theoretical relation for streamline flow in any fibrous bed of high porosity is obtained. Correction tor appreciable mean-free path of the molecules of the fluid is provided. C. F. Bonilla, USA

Geophysics, Meteorology, Oceanography

(See also Rev. 2825)

3090. Truesdell, C., On the effect of a current of ionized air upon the earth's magnetic field, *J. geophys. Res.* **55,** 3, 247–260, Sept. 1950.

A method for determining position and intensity of source of local geomagnetic disturbance is described. When a local geomagnetic perturbation is caused by motion of conducting air in earth's magnetic field, a simple equation satisfied by the small magnetic field in question is derived from Maxwell's fundamental equations under suitable assumptions. The equation has the same form as the Poisson equation, whereas volume density is replaced by magnetic density vector which includes divergence and gradient of wind velocity. The problem thus becomes equivalent to the one of Newtonian potential. If disturbance originates in a confined volume, behavior of disturbance at large distances from center follows an inverse first-power law. From magnetic observations at four stations, it is possible to determine position of center and intensity of disturbance. A graphical method is devised by author, the method being analogous to determination of earthquake origin. Reviewer believes that the method will be useful for studying geomagnetic disturbance associated with migration of anomalous ionization in ionosphere, and like problems. T. Rikitake, Japan

3091. Schnitz, H. P., On determination of the vertical motion as a consequence of earth friction from the pressure field (in German), *Meteor. Rundsch.* **2,** 7/8, 193–196, July/Aug. 1949.

3092. Masuda, Y., On the method of computing vertical motion in the atmosphere, *Pap. Meteor. Geophys. meteor. Res. Inst. Tokyo,* **1,** 1, 1–28, Oct. 1950.

Three methods are proposed for obtaining the vertical velocity from single station temperature soundings with as little additional data as possible. The first assumes the motion adiabatic and requires knowledge of the neighboring horizontal temperature field and wind field, or contours of an isobaric surface. The second is designed to depend only on single-station soundings and uses the vertical and time rates of change of the lapse rate. To develop both, the geostrophic wind equation is used freely, but with no discussion of its validity—is not vertical motion mainly associated with ageostrophic winds? In the second, the horizontal advection of lapse-rate changes has to be ignored. The third method uses the adiabatic perturbation technique and is, therefore, of restricted application, and author considers it too complicated for application. Finally, the first method is modified for wet adiabatic changes.

Applications are made to cases where the motion is anything but geostrophic! Direction of movement of a typhoon is claimed to be associated with features of the isopleths of vertical velocity, but nothing can be learned in that respect that is not evident from pressure tendencies.

Methods based on the adiabatic assumption have been tried in Europe and America, where the network of stations is far closer than around Japan, and are of very doubtful value in forecasting, and in no case compare with vorticity methods of evaluating the effect of vertical motion. R. S. Scorer, England

3093. Magata, M., Dynamics of the eye of storm, *Pap. Meteor. Geophys. meteor. Res. Inst. Tokyo,* **1,** 1, 29–37, Oct. 1950.

Paper shows that in a very simplified hurricane model it is possible for a calm "eye" to occur at the central region. Model chosen is a symmetric, steady frictionless circulation, finite in the radial direction. By assuming a polytropic atmosphere, the equations of motion can be integrated exactly, and a calm region near the storm center appears. This work verifies an earlier approximate integration by Wadati and Sakata [*J. meteor. Soc. Japan, Sec. Ser.* **XXI,** no. 10, 1944]. Descending motions within the eye are shown to be possible for eyes of large radius. The space distribution of vertical velocities, horizontal velocities, and pressures are in reasonable agreement with observations, the only large disagreement being the theoretical result that the radius of the eye should decrease with increasing pressure difference between outer limit of storm and eye. Reviewer feels, however, that significance of paper lies in the fact that such a very simplified model shows the feature of a calm center, and that the presence of the eye may be quite independent of friction, condensation, baroclinicity, etc., all of which have been omitted from this study.
Joanne Starr Malkus, USA

3094. Munk, W. H., On the wind-driven ocean circulation, *J. Meteor.* **7,** 2, 79–93, Apr. 1950.

On the basis of recent investigations of Rossby (1936), Sverdrup (1947), and Stommel (1948), author resumes Ekman's effort of 1923 and 1932 to account theoretically for the main features of oceanic circulation. From Sverdrup's work, author retains the use of the momentum per unit volume integrated over the vertical ("mass transport"). With Rossby, *lateral* friction, associated with horizontal exchange of vorticity, is assumed as the dissipative force. From Stommel, the assumption of a rectangularly bounded ocean and the way of handling the Goriolis forces is retained. These elements are fused into a new and successful theory. Using the equator as the x-axis, the northward direction as the y-axis, and the vertical upward from a level surface, assumed as plane, as the z-axis, author shows that the problem is governed by the following linear differential equation with non-constant coefficients:

$$[A\ (\partial^2/\partial x^2 + \partial^2/\partial y^2)^2 - (df/dy)\ (\partial/\partial x)]\ \psi + [\text{curl}\ \tau]_z = 0$$

where ψ is the mass transport stream function, A the effective kinematic eddy viscosity (assumed to be a constant), f twice the vertical component of the earth's angular velocity, and $[\text{curl}\ \tau]_z$ the vertical component of the wind-stress vorticity. Using for the computation of τ the *observed* wind distributions, author solves the differential equation, represents the results graphically, compares them with observed facts, and bases upon them a new classification of oceanic currents. P. Neményi, USA

3095. Hsieh, Yi-Ping, On the formation of shear lines in the upper atmosphere, *J. Meteor.* **7,** 6, 382–387, Dec. 1950.

At first, author gives a descriptive case history of an unusual weather situation in the upper air without much development near the ground. The deepening of a cold trough aloft is followed occasionally by a sharpening of the trough until the currents on either side move in almost opposite directions. Then the trough loses its initial wavelike structure and becomes a shear line. Such a development is nicely illustrated with maps at several levels.

The subsequent attempt at explanation is less convincing. Author shows qualitatively that cold air sinks near the center of

the shear line and that space distribution of sinking motion differs from other cases where no shear line resulted. This "direct solenoidal circulation" is held responsible for the development. No dynamical model, however, is advanced and it remains obscure why the field of vertical motion, as inferred by the author, should result in any particular field of horizontal motion.

Herbert Riehl, USA

3096. **Haskell, N. A., Asymptotic approximation for the normal modes in sound channel wave propagation,** *J. appl. Phys.* **22,** 2, 157–168, Feb. 1951.

Paper considers wave propagation from point source in medium having variable sound velocity in one direction with one or more minima. Solution could be adapted to ocean, but here it is found for atmosphere. Sound velocity is assumed to decrease with increasing altitude, then increase to value above velocity at earth's surface, then decrease monotonically. Undamped normal mode solutions are found which sum to a geometrical ray theory modified by diffraction. Example presented of source and receiver, both on earth's surface, shows relative amplitude distribution with horizontal distance from source. Diffraction spreads wave energy into shadow zones, so amplitude everywhere beyond third wave zone is greater than for equal point source acting in medium of constant velocity.

Method assumes local irrotational solution through use of velocity potential function, with simple correction factor involving medium density ratio found by comparing computed acoustic energy flux density with that found by ray geometry. Normal modes are found by asymptotic methods. Sum of high-order modes are converted to equivalent integral, which leads to modified geometrical ray theory. Incomplete Fresnel and Airy integrals are used to compute amplitude distribution.

Robert B. Green, USA

3097. **Wagemann, H., Calculations for theory of cyclones** (in German), *Meteor. Rundsch.* **3,** 9/10, 193–199, Sept./Oct. 1950.

The equations of motion are integrated for small perturbations in a basic flow, including effects of advection and vertical motions on the potential temperature. Usual boundary condition of zero vertical motion at the ground and the introduction of frontal surfaces permit determination of stability of the disturbances. Instability exists when the slope of the front decreases, wind discontinuity decreases, temperature difference across the front increases, and the instability of the adjacent air masses becomes greater. Rate of conversion of the wave to a low pressure center is proportional to the horizontal temperature gradient.

Author claims that close examination will show that all of the modern cyclone theories are derived from a common physical process.

Lester Machta, USA

Lubrication; Bearings; Wear

(See also Revs. 2853, 2935)

3098. **Lane, T. B., Scuffing temperatures of boundary lubricant films,** *Brit. J. appl. Phys., Suppl.* 1, 35–38, Jan. 1951.

The postulate of Blok [*Soc. auto. Engrs. J.* **44,** p. 193, 1939], that lubrication will fail when temperature in the contact area reaches a value characteristic of the lubricant and sliding system, is confirmed by experiments on a two-ball machine. This machine consists of two balls in rubbing contact, each rotating at arbitrary speeds in either direction about axes which are parallel but somewhat displaced, so that the rubbing area wipes out a circular track on both balls and various proportions of rolling combined with sliding can be introduced. The load necessary to produce scuffing of the balls during a 50-sec run is recorded. Results show that for the range of mineral oils tested, the failure temperature which is calculated from the applied load increases with viscosity.

John T. Burwell, Jr., USA

3099. **Šmerák, V., Wear of plain bearings,** *Engng. Rev., Prague* no. 2, 10–16, Apr. 1950.

Author discusses the sensitivity of wear to small variations in surface conditions and presents data to show effects of boundary and semi-dry lubrication on wear. He concludes that an objective comparison of the wear resistance of various metal combinations and lubricants can be obtained only through a testing cycle which passes through the transition from fluid to semi-dry conditions of lubrication. He describes in detail a wear machine (SKODA) designed for this purpose and comprising essentially a unidirectionally loaded journal bearing in which the shaft oscillates rather than rotates. No provision is made for measuring friction, but an electrical resistance device for measuring oil-film thickness is described. Method used to determine loss of material through wear is not described.

Charles D. Strang, USA

3100. **Casacci, S. X., and Peuchmaur, A., Tests on the functioning of large turbine thrust bearings** (in French), *Houille blanche* **6,** 1, 23–43, Jan.-Feb. 1951.

First part of article is devoted to a review of the methods used by different experimenters for measuring friction torque, oil-film thickness, temperature, and pressure in hydrodynamic bearings. Second part describes experiments on the tilting pad-type bearings of a Francis turbine in the power station at Drac Inferieur. Friction torque was measured by an assemblage of resistance strain gages on the shaft, oil-film thickness by four capacity electrodes incorporated in the surface of one of the pads, pressure and temperature distribution by numerous tapping points, and thermocouples distributed among the six pads of the complete bearing. Measured oil-film thickness corresponded closely with that predicted by theory.

Authors take into account the "dashpot" effect $\partial h/\partial t$ during deceleration and demonstrate that a hydrodynamic film persists for a short period after the bearing has come to rest.

F. T. Barwell, Scotland

3101. **Hisada, T., and Tsugawa, K., On the rolling friction,** *J. mech. Lab., Tokyo* **4,** spec no., 9–21, Mar. 1950.

Friction of a roller is assumed to be due to fluid or viscous forces and to solid or hysteresis forces. Experiments are described using a pendulum supported by a roller and also a spring-mass system in which the mass moves on two rollers. Measuring technique makes use of small mirrors. The starting moment is obtained by tipping the support. The dynamical friction is resolved into parts due to solid friction and due to fluid resistance. Author says effects of air resistance and hysteresis of coil spring were eliminated, but does not say how. Curves show effect of load on roller, radius of roller, surface finish, and lubricant (which increases the resistance considerably). Analysis is assumed to extend to knife edges by letting the roller diameter approach zero. From this new method the friction of knife edges increases as the length increases, which is just the reverse of an earlier analysis made by the British Board of Trade. Several typographical errors were noted.

W. B. Stiles, USA

3102. **Barwell, F. T., and Milne, A. A., The lubrication of rough steel surfaces by a series of metallic soaps,** *Brit. J. appl. Phys., Suppl.* 1, 44–48, Jan. 1951.

Because metallic soaps are generally employed as a vehicle for oil in mineral-base greases, this study should prove useful in determining the role of soaps in the boundary lubricating proper-

ties of such greases. Friction experiments were run with a spherically ended, hard-steel slider rubbing against a flat, soft-steel plate. Lubricants tested include metallic soaps, a fatty acid, an ester, and a straight-chain hydrocarbon. Friction coefficients were measured as functions of velocity (0.001–0.6 cm/sec) and temperature (25–150 C).

Observations indicate that the rheological properties of the materials markedly affect friction, since all lubricants produced higher friction and greater surface damage when fluid than when solid. With the acid lubricant, friction decreased with time, suggesting a progressive ion exchange between the acid and the metal surface with possible formation of the iron soap.

Eugene M. Simons, USA

Marine Engineering Problems

(See also Revs. 2930, 2977)

3103. Troost, L., Open water test series with modern propeller forms. Part 3. Two-bladed and five-bladed propellers—Extension of the three and four-bladed B-series, *N. E. Coast Instn. Engrs. Shipb. Trans.* **67,** part 3, 89–130, Jan. 1951.

Results of experiments in open water are presented for the following related series of propellers.

No. of Blades	Disk-Area Ratio
2	0.30
3	0.35, 0.50, 0.65
4	0.40, 0.55, 0.70
5	0.45, 0.60

These series are of the Wageningen B-type, namely, wide tips, airfoil sections up to 0.7 R, ogival sections at tips. Propellers have a constant face pitch with the exception of the 4-bladed propellers which have pitch reduction of 20% toward the boss. For constructional and analytical purposes the results are presented in the form of (a) power coefficient B_p vs. diameter constant δ; (b) thrust coefficient B_u vs. diameter constant δ; (c) dimensionless rpm coefficient μ vs. dimensionless thrust coefficient σ.

Because of pitch reduction of 4-bladed propellers, possibility of comparing performance of screws of varying number of blades is to some extent vitiated, for thereby a deviation is introduced from an otherwise essentially methodical series. Although on basis of available experimental results this difference in pitch distribution is admittedly small and can be allowed for in determining rpm, one wonders why it was introduced at all, there being no particular merit to it.

Another criticism lies in the insufficiently high Reynolds number at which model propellers were tested ($R_{n.7}$ from 2.0×10^5 to 2.65×10^5). Recent report to the American Towing Tank Conference on evaluation of methodical series covering wide range in Reynolds number reveals that minimum $R_{n.7}$ should be from 3×10^5 to 4×10^5, depending on blade outline, nose shape, etc. Necessity of running model propellers at higher Reynolds numbers than for this series is confirmed by van Lammeren, a colleague of author [*N.E. Coast Instn. Engrs. Shipb.* **65**, p. 115].

Even with the foregoing exceptions, which detract from rigor and elegance, the complete series does represent a powerful experimental contribution to design of screw propellers. Because blade outline and sections are of modern concept and have good cavitation characteristics, curves presented will find wide application in design. Manley St. Denis, USA

3104. Edstrand, H., Cavitation tests with model propellers in natural sea water with regard to the gas content of the water and its effect upon cavitation point and propeller characteristics, *Medd. SkeppsProvAnst. Göteborg*, no. 15, 80 pp., 1950.

3105. Weinblum, G. P., Analysis of wave resistance, *David W. Taylor Mod. Basin Rep.* 710, 102 pp., Sept. 1950.

Report gives complete survey of theoretical and experimental contributions to the problem of functional relation between ship form and wave resistance, relating calculations based on Michell's integral to experimental values. It shows in an authoritative way the limits of practical application of theory and the outlook on further systematical research. The study, primarily from the viewpoint of the theoretical naval architect, implies original treatment of mathematically defined ship lines, influence of viscosity, interaction between ship and propeller, restriction of waterway section, and submerged bodies. A complete list of references is included. Author is one of the few prominent workers in this field and his study is recommended as a brilliant introduction to the subject. L. Troost, Holland

3106. Todd, F. H., Skin friction resistance and the effects of surface roughness, *David W. Taylor Mod. Basin Rep.* 729, 13 pp. Sept. 1950.

In the opinion of the David Taylor Model Basin, the Schoenherr line should continue to be used for the extrapolation of model results to give ship predictions. Some correction to model results for very small models may be necessary, due to the effects of transverse curvature. Theoretical and experimental work to evaluate this correction are in progress. All model data should be corrected to a standard temperature of 59 F through use of correct value of ν in the Reynolds number. Available data from full-scale trials are insufficient as yet to allow of special roughness allowances for different types of paint and classes of ship. It is recommended that present allowance of +0.0004 for clean new vessels be continued. From author's summary

3107. Harvald, S. A., The dependence of wake on shape of rudder, trim, and stern wave (in Swedish), *Medd. SkeppsProvAnst. Göteborg*, no. 13, 56 pp., 1949.

3108. Servello, A., The total fineness coefficient φ and the ratio $V/(L)^{1/2}$ in the design of merchant ships (in Italian), *Riv. marittt.* **82,** 12, 463–482, Dec. 1950.

Author proposes new empirical relationship between block coefficient, φ, and speed-length ratio, V/L, as follows: $\varphi = \lambda[1/a^2(V/L^{1/2})^2 + b] \pm 0.03\Delta\lambda$, where φ is block coefficient; $a = 3V/L^{1/2} + 0.1(V/L^{1/2})^2$; b depends on type of vessel and varies between −0.01 (high-speed passenger liners) and 0.006 (large tankers); λ is length-beam ratio; $\Delta\lambda$ deviation of λ from a tabulated mean; L waterline length in meters; V speed in knots.

Evaluation of proposed formula against 48 designs of various types proves it is superior to the well-known relations due to Lovett, Ayre, and Alexander. Manley St. Denis, USA

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